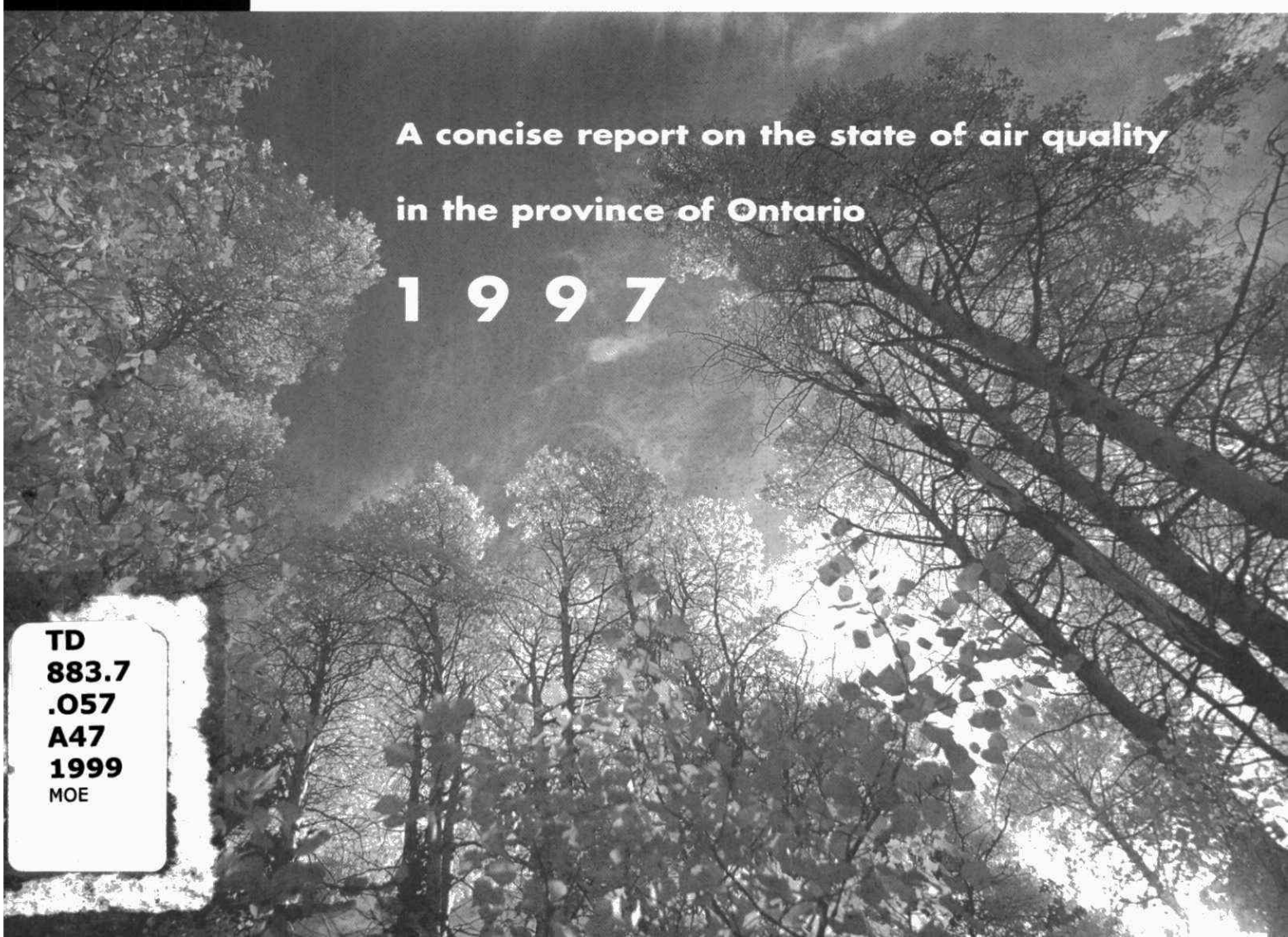
Ontario

Air Quality in Ontario



A concise report on the state of air quality in the province of Ontario

1997

Acknowledgments

This report has been prepared by the staff of the Environmental Monitoring and Reporting Branch of the Ministry of the Environment with contributions by the staff of the regional offices of the Operations Division and Laboratory Services Branch. Canada's National Air Pollutant Surveillance program is also acknowledged.

Message from the Honourable Tony Clement

Minister of the Environment

As Minister of the Environment for the Harris government, I want the people of Ontario to know we are strongly committed to ensuring they have clean and healthy air to breathe. They deserve no less.

The Air Quality in Ontario 1997 report is encouraging because it documents a steady improvement in provincial air quality between 1988 and 1997. Significant reductions were made for a number of airborne contaminants, including total reduced sulphur compounds (50 per cent), carbon monoxide (32 per cent), sulphur dioxide (23 per cent) and nitrogen dioxide (10 per cent). These numbers are more impressive in light of increases in Ontario's population and economic activity during the same period.

In 1997 Ontario's Air Quality Index indicated that our air was good to very good 95.5 per cent of the time. Volatile organic compounds, major contributors to smog, were measured at levels well within provincial air quality criteria. Overall, Toronto's air was better than that of most international cities to which it was compared.

This report is valuable because, in addition to indicating where progress is being made, it shows where more work is needed: ground-level ozone and inhalable particles – the chief components of smog – were the pollutants that most often exceeded provincial air quality criteria in 1997.

With half of Ontario's smog originating from sources in the United States, the Harris government is working to ensure the reduction of transboundary pollution from south of the border. We are encouraged by a U.S. court's recent decision to grant Ontario intervenor status to support the U.S. Environmental Protection Agency's new rules for nitrogen oxide reductions. This is an important development because it indicates a recognition that U.S. emissions are a source of our smog problem.

Here in Ontario, however, there is much we can all do to combat smog and other forms of air pollution.

The Ontario government is doing its part, and is developing partnerships with people from all walks of life to protect provincial air quality. Through Ontario's Smog Plan, a wide range of industries and groups are working to reduce smog-causing emissions by 45 per cent by 2015. Actions already have been taken, or are being planned, to achieve half that ambitious goal.

Drive Clean, Ontario's vehicle emissions testing program, is an integral part of the Smog Plan. Vehicles, the largest single source of smog-causing emissions in the province, must pass a clean air test. Cars that fail the test must be repaired and retested. Drive Clean is under way for cars and light trucks in the Greater Toronto Area and Hamilton-Wentworth Region. The program will eventually cover 4.7 million light-duty vehicles in southern Ontario. Heavy-duty diesel trucks and buses across the province will soon be covered as well. These vehicles are an important source of microscopic dust particles that can infiltrate the lungs and aggravate respiratory problems.

When fully implemented, Drive Clean is expected to reduce emissions of smog-related contaminants, such as nitrogen oxides and volatile organic compounds, by 22 per cent, and microscopic dust particles by six per cent.

Drive Clean is complemented by a number of other initiatives, including the on-road Smog Patrol, which targets the most grossly-polluting vehicles on Ontario roadways. As well, we're working to educate people about air quality issues and how all of us can reduce our contribution to air pollution. Partners in Air teaches young people about air issues, while the mobile Smog Rover identifies polluting vehicles and educates the public about the importance of reducing vehicle emissions.

We are currently strengthening and clarifying the standards and regulations that protect Ontario's air. Among recent developments are a regulation requiring less polluting gasoline formulas during summer and an interim standard for inhalable

particulate matter (microscopic dust particles).

To ensure compliance with anti-pollution legislation, the Ontario government has passed the *Environmental Statute Law Amendment Act* to close the loopholes that have enabled polluters to break the law with impunity. Serious polluters will incur serious penalties.

We have invested more than $4 million since 1995 in the air monitoring network which measures Ontario's progress in protecting and improving its air. This second-to-none network includes an air monitoring bus which travels to many parts of the province to measure smog-causing pollutants and determine their effects.

The Air Quality in Ontario 1997 report shows that real progress is being made in the fight for Ontario's air. We believe that all of us can – and must – do much more. Our success depends on getting everyone involved. The result will be cleaner and healthier air, both for ourselves and for future generations.

August 1999

Table of Contents

TABLES

FIGURES

1997 Highlights

- Air quality in Ontario continued to improve between 1988 and 1997. Provincial levels of total reduced sulphur compounds were reduced by 50 per cent in that period, carbon monoxide by 32 per cent, sulphur dioxide by 23 per cent and nitrogen dioxide by 10 per cent.

- In 1997, Ontario's Air Quality Index reported good to very good air quality readings 95.5 per cent of the time.

- Three air quality advisories were called in 1997, covering a total of six days.

- Measured VOC concentrations in 1997 indicate that levels are well below existing provincial criteria.

- On an international basis, using the most recent available data, Toronto's air was better than most of the cities with which it was compared, including New York, Chicago and Detroit.

- Ground-level ozone and inhalable particles – the major components of smog – were the pollutants that most often exceeded the provincial ambient air quality criteria. More than 50 per cent of the ozone and a considerable amount of inhalable particles were caused by air pollution from the U.S.

Introduction

Since 1971, the Ontario Ministry of the Environment has been monitoring air quality in Ontario and using this information to:

- inform the public in real time about outdoor air quality;
- provide air quality advisories for public health protection;
- assess Ontario's air quality and evaluate trends;
- identify areas where criteria are exceeded and identify the origins of pollutants;
- provide the basis for air policy development;
- provide quantitative measurements to enable abatement of specific pollutant sources;
- assess the levels of pollutants from U.S. sources and their effects on Ontario;
- provide air quality researchers with data linking environmental and human health effects to air quality.

Air quality is measured on the basis of emissions of contaminants into the atmosphere from both human and natural activity, and from their atmospheric interactions. Local air quality is influenced by emissions from motor vehicles and other transportation sources, industrial sources, and meteorological and topographical conditions.

Distant sources are significant contributors to local air quality for contaminants that undergo long-range transport and transformation, such as ozone, fine particles, trace metals, toxics and the components of acid rain.

Table 1.0 shows the relationship between monitored air pollutants and current air issues. Individual contaminants can have impacts (usually adverse but sometimes beneficial) on a number of air issues at the same time. Such interactions require integration of air issues in order to see the complete picture.

This report, 27th in a series, summarizes the state of ambient air quality in Ontario in 1997. It covers measured levels of ozone (O_3), particles and other criteria contaminants such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and total reduced sulphur (TRS) compounds. Results are also presented for the measurement of a number of

Table 1.0
Linkages Between Air Pollutants and Air Issues

	Smog	Global Warming	Urban Air Quality	Acid Deposition	Health	Aesthetics
Ozone	yes	yes	yes	yes	yes	
Sulphur Dioxide	yes	yes	yes	yes	yes	yes
Carbon Monoxide			yes		yes	
Oxides of Nitrogen	yes	yes	yes	yes	yes	yes
Volatile Organic Compounds	yes	yes	yes		yes	yes
Toxics			yes		yes	
Particulates	yes	yes	yes	yes	yes	yes
Total Reduced Sulphur Compounds			yes		yes	yes

airborne organic compounds for 1997. In addition, the report summarizes the 1997 Air Quality Index statistics from the real-time air quality index information system, examines regional smog episodes in detail and provides a regional/national/international perspective on air quality.

The focus of this year's publication is to report on the state of ambient air quality. The source-related monitoring statistics, as in the past, will be presented in a separate appendix document, along with the ambient data.

Increased emphasis is now being directed to ozone and inhalable (PM_{10}) and respirable ($PM_{2.5}$) particles, for which scientific evidence suggests significant impacts on health.

Ontario continues to benefit from one of the most comprehensive air monitoring systems in North America. The network is designed to measure air quality at more than 200 sites across the province. This network undergoes constant maintenance to ensure a high standard of quality control. Continuous real-time air quality data are reviewed, assessed and validated constantly. Action is taken immediately to correct anything that may affect the validity of the data. These measures ensure that the ambient air monitoring data are valid, complete, comparable, representative and accurate. As a result, for 1997 the network had 94.1 per cent valid data out of approximately four million data points. With this data, Ontario can make informed decisions about what needs to be done to protect our environment and improve our air quality.

Chapter 1

Overview of principal contaminants

The principal contaminants considered in this report include O_3, PM_{10}, SO_2, NO_2, CO and TRS compounds. They are also commonly referred to as criteria pollutants because Ontario has established ambient air quality criteria (AAQC) based on health and/or environmental effects. The AAQCs are used as yardsticks for measuring the success of our programs. Most of the trend information presented in subsequent chapters of this report is based on two types of data: direct measurement of ambient air concentrations and estimates of air emissions based on best available information.

For additional information on air emission estimates, please refer to the ministry's Fast Response

Table 1.1
Overview of Criteria Pollutants

Pollutant	Characteristics	Sources	Ontario Criteria	General Health Effects	General Ecological Effects
Ozone (O_3)	A colourless gas with a strong smell. Major component of summer smog.	Ozone is not emitted directly into the atmosphere. It is produced by photochemical action of nitrogen oxides and volatile organic compounds.	1 h average 80 ppb	Irritation of the lungs and difficulty in breathing. Exposure to high concentrations can result in chest tightness, coughing and wheezing.	Damage to agricultural crops, ornamentals, forests and natural vegetation.
Total Suspended Particles (TSP)	Particles of solid or liquid matter that stay suspended in air in the form of dust, mist, aerosols, smoke, fume, soot, etc. Size range 0.1-100 microns.	Industrial processes including combustion, incineration, construction, metal smelting, etc. Also motor vehicle exhaust and road dust. Natural sources such as forest fires, ocean spray and volcanic activity.	24 h average 120 µg/m³ 1 y average 60 µg/m³	The smaller the particle the greater the effect on health. Significant effects for people with lung disease, asthma and bronchitis. See PM_{10} below.	Damage to vegetation, deterioration in visibility and contamination of soil.
Inhalable Particles (PM_{10})	Same as TSP except size range of particles is less than 10 microns.	Same as TSP	24 h average 50 µg/m³	Increased hospital admissions and premature deaths.	Same as TSP.
Total Reduced Sulphur (TRS)	Offensive odours similar to rotten eggs or cabbage	Industrial sources include steel industry, pulp and paper mills and refineries. Natural sources include swamps and marshes.	1 h average 27 ppb (kraft pulp mill)	Not normally considered a health hazard. They are the primary cause of odours.	
Sulphur Dioxide (SO_2)	Colourless gas with a strong odour similar to burnt matches.	Electric utilities and non-ferrous smelters . Also primary metal processing, iron ore smelters, pulp and paper, petroleum refineries, etc.	1 h average 250 ppb 24 h average 100 ppb 1 y average 20 ppb	Breathing discomfort, respiratory illness, aggravation of existing respiratory and cardiovascular disease. People with asthma, chronic lung or heart disease are most sensitive to SO_2.	Leads to acid deposition, which causes lake acidification, corrosion and haze. Damage to tree leaves and crops.
Nitrogen Dioxide (NO_2)	Gas with a pungent and irritating odour.	Automobiles, thermal power plants, incineration, etc. Natural sources include lightning and soil bacteria.	1 h average 200 ppb	Increasing sensitivity for people with asthma and bronchitis.	Leads to acid deposition: adverse effect on vegetation.
Carbon Monoxide (CO)	Colourless, odourless, tasteless and poisonous gas.	Major source is transportation sector; i.e., road vehicles, aircraft and railways.	1 h average 30 ppm 8 h average 13 ppm	Impairment of visual perception, work capacity, learning ability and performance of complex tasks.	

Emission Document (FRED), version 4, November 1998.

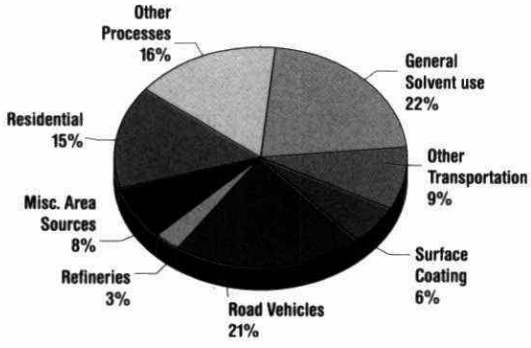
A brief description of the criteria pollutants according to their characteristics, sources and effects is provided below and summarized in Table 1.1 along with the current Ontario ambient air quality criteria.

Ground-level ozone

Characteristics: O_3 is a colourless, odourless gas at ambient concentrations, and is a major component of smog.

Sources: Ground-level ozone is not emitted directly into the atmosphere. It results from chemical reactions between volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. High levels typically occur from May to September, between noon and early evening. Figure 1.1 shows estimates of Ontario's VOC emissions caused by human activity, by sector. Transportation modes account for approximately 30 per cent of VOC emissions. Owing to the large forested area in Northern Ontario, biogenic emissions of certain VOCs are significant – approximately three times those from sources caused by human activity. The sources of NO_x are in the nitrogen dioxide section below.

Figure 1.1
Ontario VOC Emissions by Sectors
(Emissions from Human Activity, 1997 Estimates)



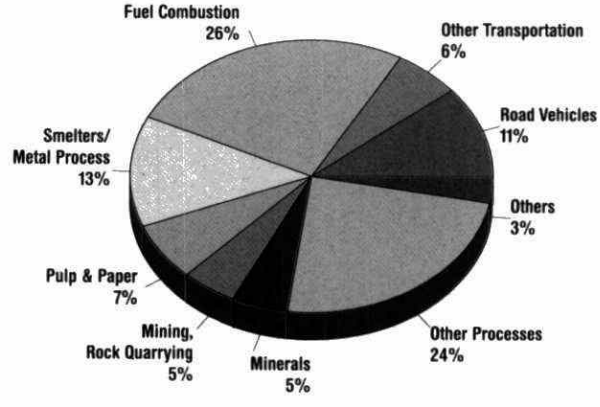
Effects: O_3 irritates the respiratory tract and eyes. Exposure to high levels of O_3 results in chest tightness, coughing and wheezing. People with respiratory and heart problems are at a higher risk. Ozone has been linked to increased hospital admissions and premature death. Ozone causes agricultural crop loss each year in Ontario and noticeable leaf damage in many crops, garden plants and trees. A recent federal/provincial scientific assessment document indicates that health effects attributable to ozone are occurring at much lower ozone levels than was thought in the past. This new evidence will be reviewed and used in the process to develop new Canada-wide standards for ground-level ozone that will ultimately lead to better protection of people's health and the reduction of ozone levels in Ontario.

Particles

Characteristics: Particles in the atmosphere consist of either solid particles or fine liquid droplets. They include aerosols, smoke, fumes, dust, fly ash and pollen. Composition varies with place and season. Particles in the atmosphere have been characterized according to size mainly because of the different health effects from particles of different diameters. Particles with diameters less than 100 microns are classified as total suspended particles (TSP). Particles less than 10 microns and 2.5 microns in diameter are defined as inhalable particles (PM_{10}) and respirable particles ($PM_{2.5}$), respectively. The smaller the particle size the further the particle will penetrate into the lungs.

Sources: The majority of particle emissions from human activity falls into the size range that is classified as TSP. PM_{10} sized particles (Figure 1.2) are emitted from industrial sources such as fuel

Figure 1.2
Ontario PM_{10} Emissions by Sectors
(Emissions from Area/Point/Mobile Sources, 1995 Estimates)



[1] Emissions from road dust, construction, agriculture, etc. are not included.
[2] Emissions from open sources from the smelters are not available.

combustion, energy production, incineration, construction, mining, metal smelting and processing. In the urban airshed, motor vehicle exhaust, residential wood combustion and road dust are the major sources. Natural sources include wind-blown soil, forest fires, ocean spray and volcanic activity. $PM_{2.5}$ material is primarily formed from chemical reactions in the atmosphere and through combustion.

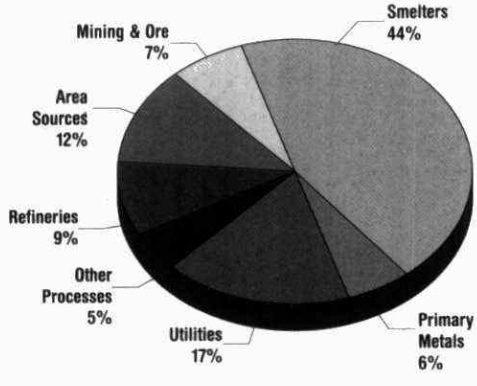
Effects: The greatest effect on health is from particles 10 microns or less in diameter (PM_{10}), which can aggravate bronchitis, asthma and other respiratory diseases. People with asthma or cardiovascular or lung disease, as well as children and elderly people, are considered to be the most sensitive to the effects of particles. Particles are also responsible for corrosion, soiling, damage to vegetation and visibility reduction.

Sulphur dioxide (SO_2)

Characteristics: SO_2 is a colourless gas. It smells like burnt matches. It can be oxidized to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. SO_2 can also be oxidized to form acid aerosols. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere.

Sources: Approximately 61 per cent of the SO_2 emitted in Ontario in 1997 came from smelters and utilities. Other industrial sources include iron and steel mills, petroleum refineries, and pulp and paper mills. Small sources include residential, commercial and industrial space heating (Figure 1.3).

Figure 1.3
Ontario Sulphur Dioxide Emissions by Sectors
(Emissions from Human Activity, 1997 Estimates)



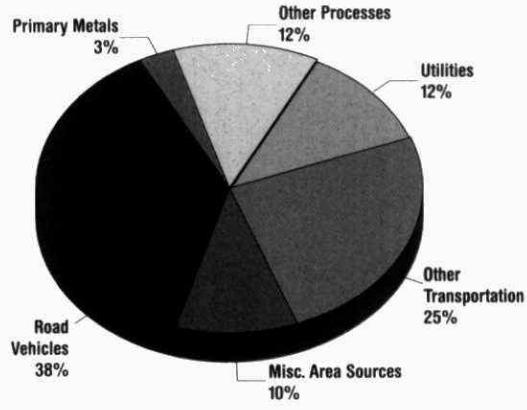
Effects: Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defences, and worsening respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are the most sensitive to SO_2. It also damages trees and crops. SO_2, along with NO_x, are the main precursors of acid rain. This contributes to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. SO_2 also causes formation of microscopic acid aerosols, which have serious health implications as well as contributing to climate change.

Nitrogen dioxide (NO_2)

Characteristics:NO_2 is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates. NO_2 also plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog. It is also a precursor to nitrates, which contribute to increased respirable particle levels in the atmosphere.

Sources: All combustion in air produces oxides of nitrogen (NO_x), of which NO_2 is a major component. Approximately 63 per cent of NO_x comes from the transportation sector in Ontario (Figure 1.4). A large part of the remaining 37 per cent comes from power generation, primary metal production and incineration. Natural sources of NO_x include lightning and the aerobic activity of soil bacteria.

Figure 1.4
Ontario Nitrogen Oxides Emissions by Sectors
(Emissions from Human Activity, 1997 Estimates)

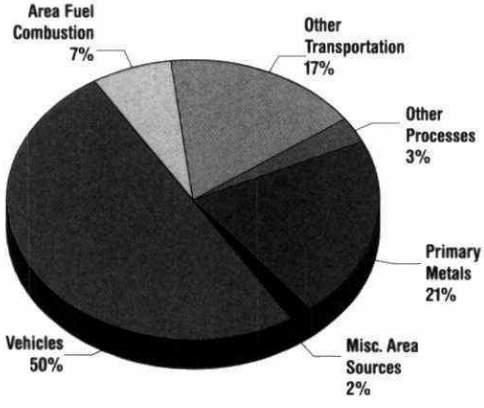


Effects: NO_2 can irritate the lungs and lower resistance to respiratory infection. Sensitivity increases for people with asthma and bronchitis. NO_2 chemically transforms into nitric acid and, when deposited, contributes to lake acidification. NO_2, when chemically transformed to nitric acid, can corrode metals, fade fabrics and degrade rubber. It can damage trees and crops.

Carbon monoxide (CO)

Characteristics: CO is a colourless, odourless, tasteless and poisonous gas produced primarily by incomplete burning of fossil fuels.

Figure 1.5
Ontario Carbon Monoxide Emissions by Sectors
(Emissions from Human Activity, 1997 Estimates)



Sources: The transportation sector accounts for 67 per cent of all CO emissions from human activity in Ontario (Figure 1.5). A large part of the remainder comes from primary metal producers (21 per cent) and from fuel combustion in space heating and industrial processes (7 per cent).

Effects: CO enters the bloodstream and reduces oxygen delivery to the organs and tissues. People with heart disease are particularly sensitive. Exposure to high levels is linked with the impairment of vision, work capacity, learning ability and performance of difficult tasks.

Total reduced sulphur (TRS) compounds

Characteristics: TRS compounds produce an offensive odour similar to rotten eggs or cabbage.

Sources: Industrial sources of TRS compounds include the steel industry, pulp and paper mills, refineries and sewage treatment facilities. Natural sources include swamps, bogs and marshes.

Effects: TRS compounds are not normally considered a health hazard. They are, however, a primary cause of odours.

Chapter 2

Ozone in Ontario

Ground-level ozone is a gas formed when nitrogen oxides and volatile organic compounds react in the presence of sunlight. Ground-level ozone is the primary component of smog and is different from the ozone layer high above the earth that protects us from the sun's harmful UV rays. The formation and transport of ozone are strongly dependent on meteorological conditions. In Ontario, elevated concentrations of ground-level ozone are generally recorded on hot, sunny days from May to September between noon and early evening.

Significant amounts of ozone and ozone-forming compounds are carried into Ontario from the U.S. During periods of widespread elevated ozone, it is estimated that more than 50 per cent of Ontario's ground-level ozone can be attributed to trans-boundary pollution. Figure 2.1 shows the area from which southern Ontario air arrives during days of widespread elevated ozone levels. Whenever high ozone was recorded, the air mass had resided over the high emission areas of the midwest U.S. and moved into Ontario.

Figure 2.1
U.S. Source Regions of Trans-boundary Ozone into Ontario

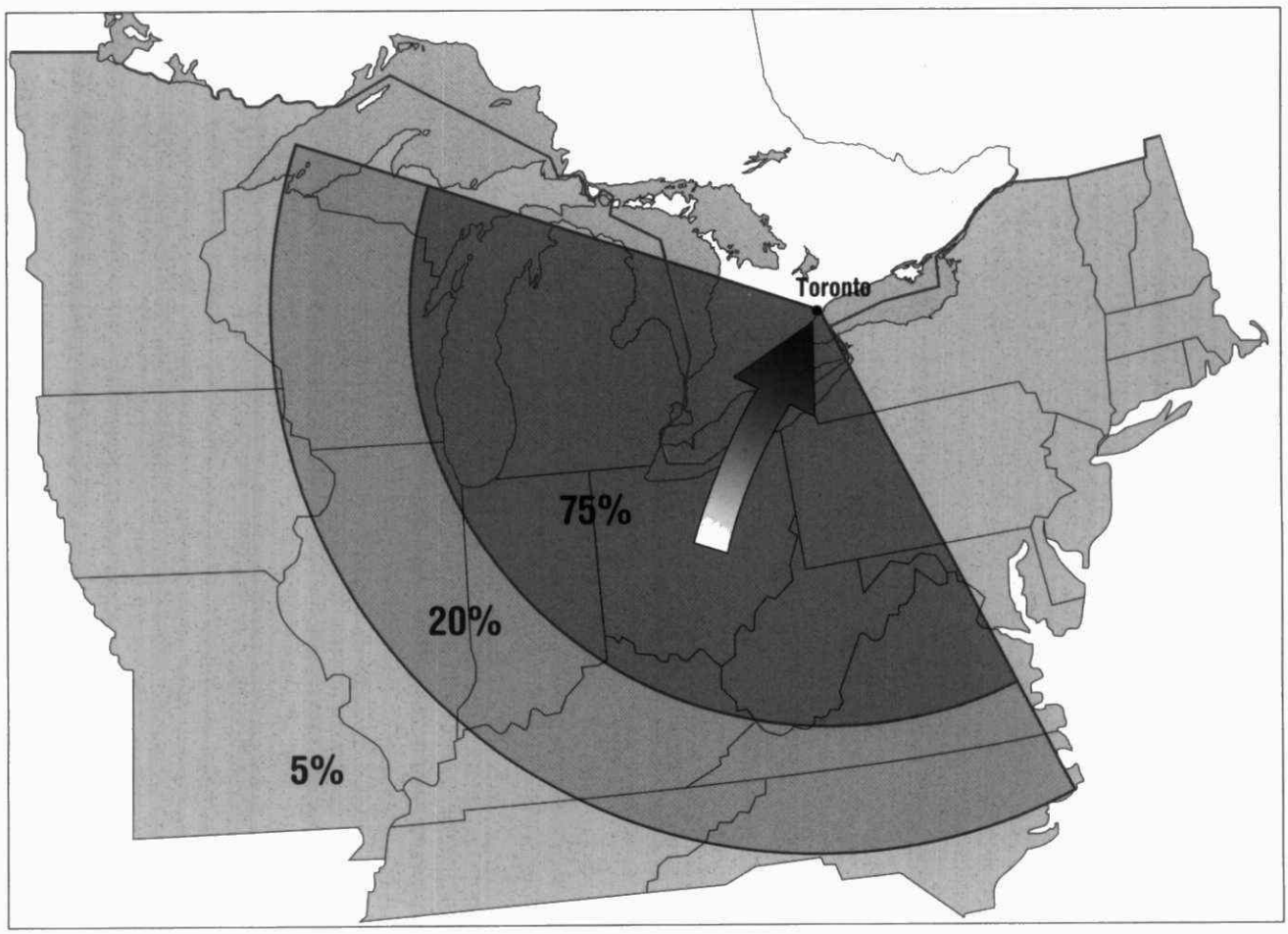
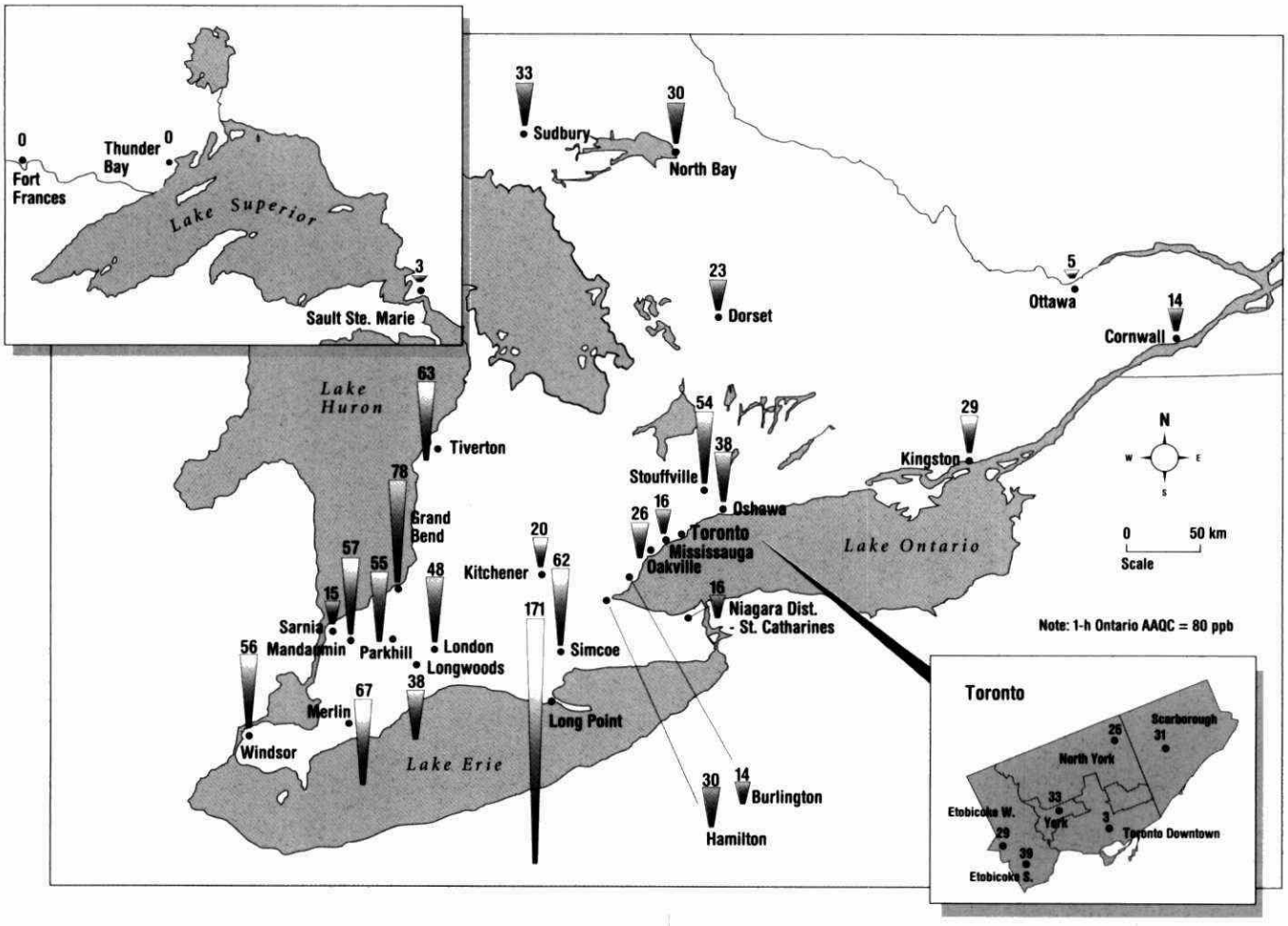


Figure 2.2
Geographical Distribution of 1-Hour Ozone Exceedances Across Ontario (1997)



Monitoring results for 1997

Ground-level ozone was monitored at 39 locations during 1997. The lowest annual mean (13.7 parts per billion) was measured at the Toronto Downtown location while the highest mean (35.2 ppb) was measured at Long Point, a rural site on the northern shore of Lake Erie. Generally, ozone is lower in urban areas because it is removed by reaction with locally emitted nitric oxides.

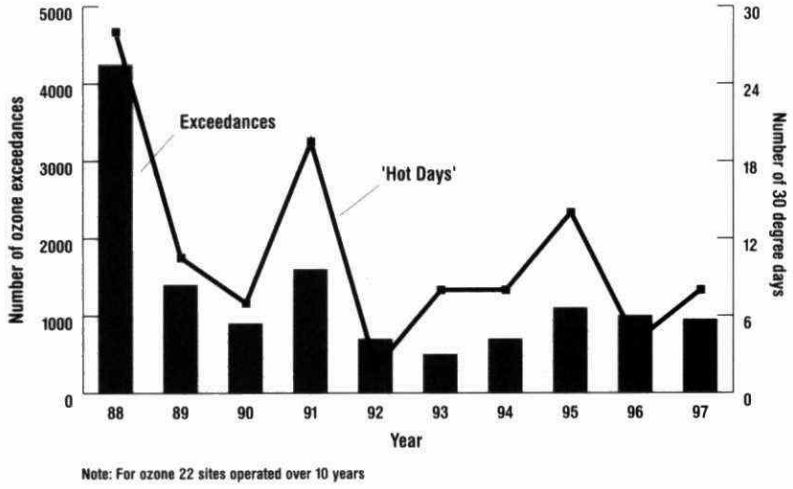
Among urban sites, Windsor University recorded both the highest one-hour concentration (107 ppb) and the greatest number of instances (56) of elevated ozone above the one-hour AAQC of 80 ppb, while the highest annual urban mean (29.0 ppb) was recorded at the Fort Frances site in Northern Ontario.

At rural sites, Grand Bend and Tiverton on the eastern shore on Lake Huron recorded the highest one-hour concentration (146 ppb) and Long Point on the northern shore of Lake Erie recorded the greatest number of instances of elevated ozone (171).

Ground-level ozone is the pollutant that exceeds its provincial ambient air quality criterion (AAQC) most often. In 1997, Ontario's one-hour ozone criterion (80 ppb) was exceeded at 37 of 39 monitoring stations. All ozone monitoring sites in southern Ontario recorded at least one hour of elevated ozone (above 80 ppb) in 1997. At these levels, people with heart and lung problems are at risk. Sensitive people may have trouble breathing and their health may be affected if they engage in vigorous exercise.

Figure 2.2 shows geographical distribution of the number of hours of elevated ozone across Ontario. The higher numbers are found at sites in the southwestern part of the province, along both the eastern shore of Lake Huron and the northern shore

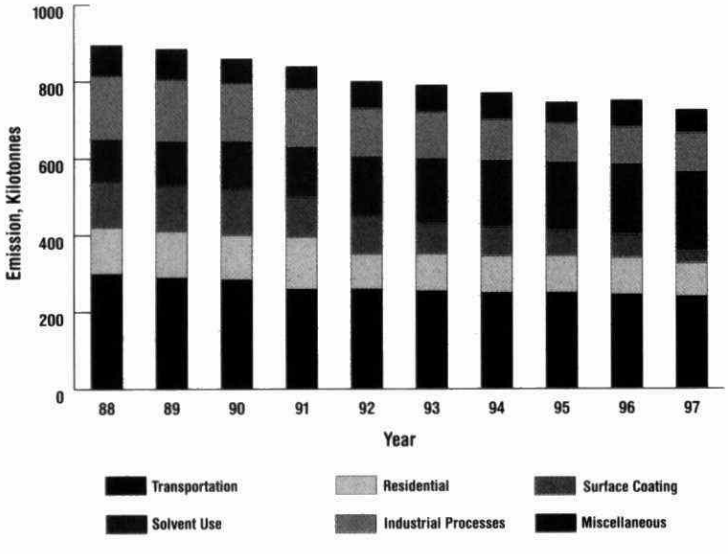
Figure 2.3
10-Year Trend for Ozone Exceedances and 'Hot' Days (1988-1997)



Note: For ozone 22 sites operated over 10 years

of Lake Erie. The importance of trans-boundary flow is reflected in the relatively higher levels measured there. As mentioned earlier, more than 50 per cent of provincial ozone levels during widespread ozone episodes are due to long-range transport of ozone and its precursors from neighbouring U.S. states.

Figure 2.4
Trend for Ontario VOC Emission Estimates (1988-1997)



Trends

Interpretation of the 10-year ambient ozone trends is complicated by meteorology and emission changes. Year to year, ozone levels are strongly influenced by weather. Figure 2.3 shows the distribution of province-wide instances of elevated ozone and the number of hot days (days with maximum air temperatures greater than 30 degrees C) for 1988 to 1997. Just as the highest number of one-hour elevated levels in 1988 (4345) are likely attributed in part to the weather (highest number of "hot" days), so probably the low numbers in 1992 (480) reflect conditions less conducive to production of ground-level ozone.

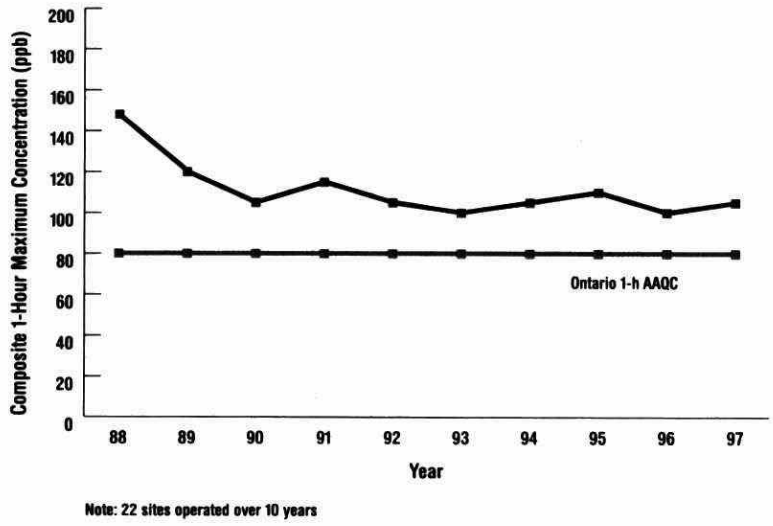
Emissions of VOCs show a decreasing trend for the overall period 1988 to 1997 (Figure 2.4). New vehicle emission standards in the early 1990s and reductions in the surface coating sector contributed to this decreasing trend. Emissions from forest fires and natural sources are not included in this trend.

The introduction of lower gasoline volatility (from 82.8 kPa to 72.0 kPa), beginning in 1989 for the summer months, has resulted in a 1.9 per cent decrease in provincial VOC emissions in 1997 and an overall 9.4 per cent reduction over the nine-year program period.

The effect of changes in VOC emissions, as a precursor, on ozone production is not obvious from the trend of ozone for 1989 to 1997. However, preliminary analysis does indicate a slight decrease in the composite peak one-hour ozone concentrations during the 1988 to1997 period (Figure 2.5). However, we must not lose sight of the meteorological variability factor mentioned earlier, which plays a significant role in ozone forma-tion as shown in the unusually hot summer of 1988.

The trend of the annual means for the 22 (15 urban and seven rural) long-

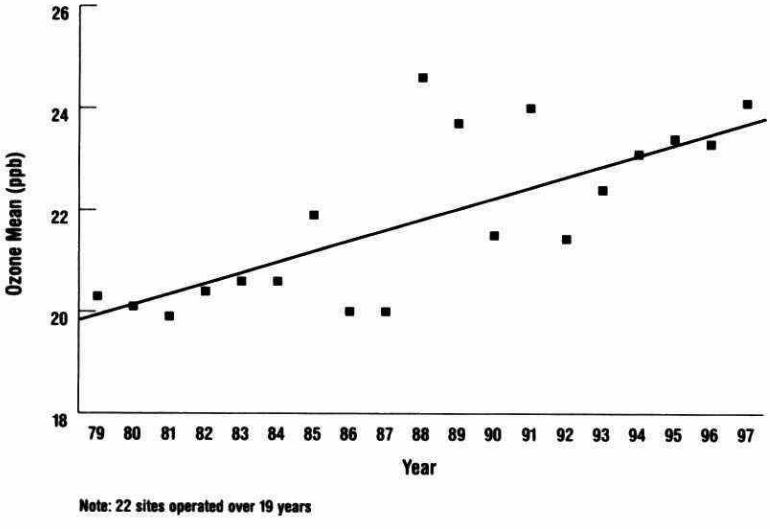
Figure 2.5
10-Year Trend for 1-Hour Maximum Ozone Concentration (1988-1997)



term ground-level ozone sites across Ontario from 1979 to 1997 is shown in Figure 2.6. It shows that there has been an overall increasing trend in the annual means during the period. This increasing trend is less obvious during the past decade. The composite averaged annual mean over this 19-year period was 22.3 ppb. If we look at the nine-year period 1979 to 1987, there were no years exceeding the 19-year average. However, during the nine-year period 1989 to 1997, every year except two recorded an annual ozone mean higher than the 19-year average. Composite annual ozone means in 1997 were 19 per cent higher than in 1979. Composite annual ozone means show an increasing trend at both urban and rural locations.

The trend of mean annual ozone levels in southern, northern and rural Ontario for 1988 to 1997 is shown in Figure 2.7. Interestingly, it shows that mean annual ozone levels in southern Ontario are consistently about 5 ppb less than those of northern Ontario and about 13 ppb less than those of rural Ontario. If we look at the mean monthly trend of ozone levels in southern versus northern Ontario over the same ten-year period, Figure 2.8, it indicates that for the late fall, winter and early spring periods, monthly ozone levels in northern Ontario are approximately twice those of southern Ontario. During the summer months of July and August, the pattern is reversed and southern Ontario records higher monthly means. Possible reasons for the trends noted above are (a) ozone sites in northern Ontario are far removed from nitrogen oxide emission areas and thus there is less removal of ozone than in southern urban areas; (b) during the late winter and early spring there is the potential for stratospheric ozone to be injected into the troposphere in northern Ontario; and (c) during the summer months ozone and its precursors are transported into southern Ontario from the midwest U.S.

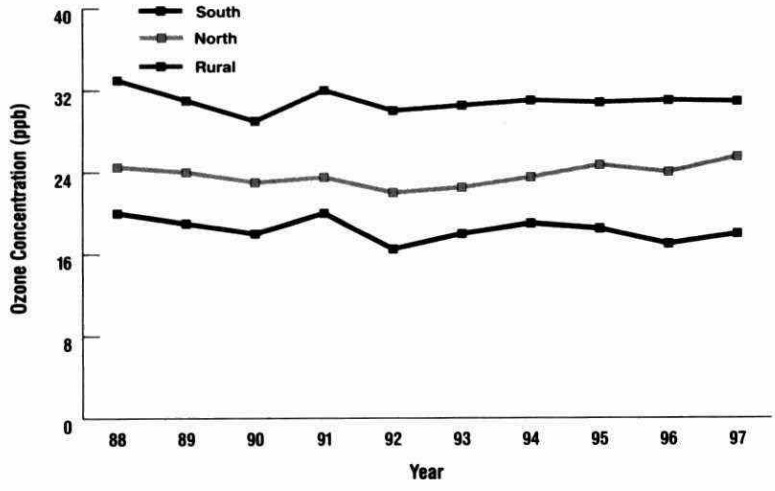
Figure 2.6
Trend for Mean Annual Ozone Levels Across Ontario (1979-1997)



Air quality advisories

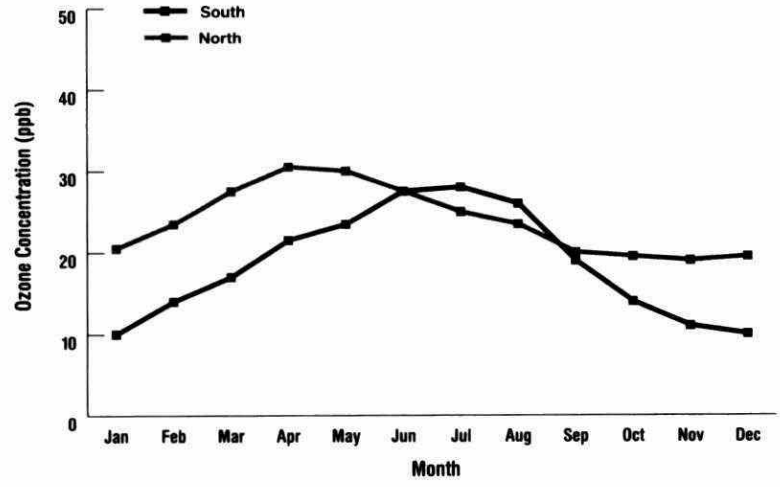
Initiated in the spring of 1993 as a joint effort between the Ministry of the Environment and Environment Canada, air quality advisories are issued to the public when elevated pollution levels are forecast due to ground-level ozone. This program builds on Ontario's Air Quality Index (AQI)

Figure 2.7
Trend for Mean Annual Ozone Levels for Southern, Northern and Rural Ontario (1988-1997)



South - Windsor, London, Hamilton, Toronto
North - Thunder Bay, Sault Ste. Marie, Sudbury, North Bay
Rural - Merlin, Simcoe, Long Point, Tiverton

Figure 2.8
Trend for Mean Monthly Ozone Levels South vs North (1988-1997)



South - Windsor, London, Hamilton, Toronto
North - Thunder Bay, Sault Ste. Marie, Sudbury, North Bay

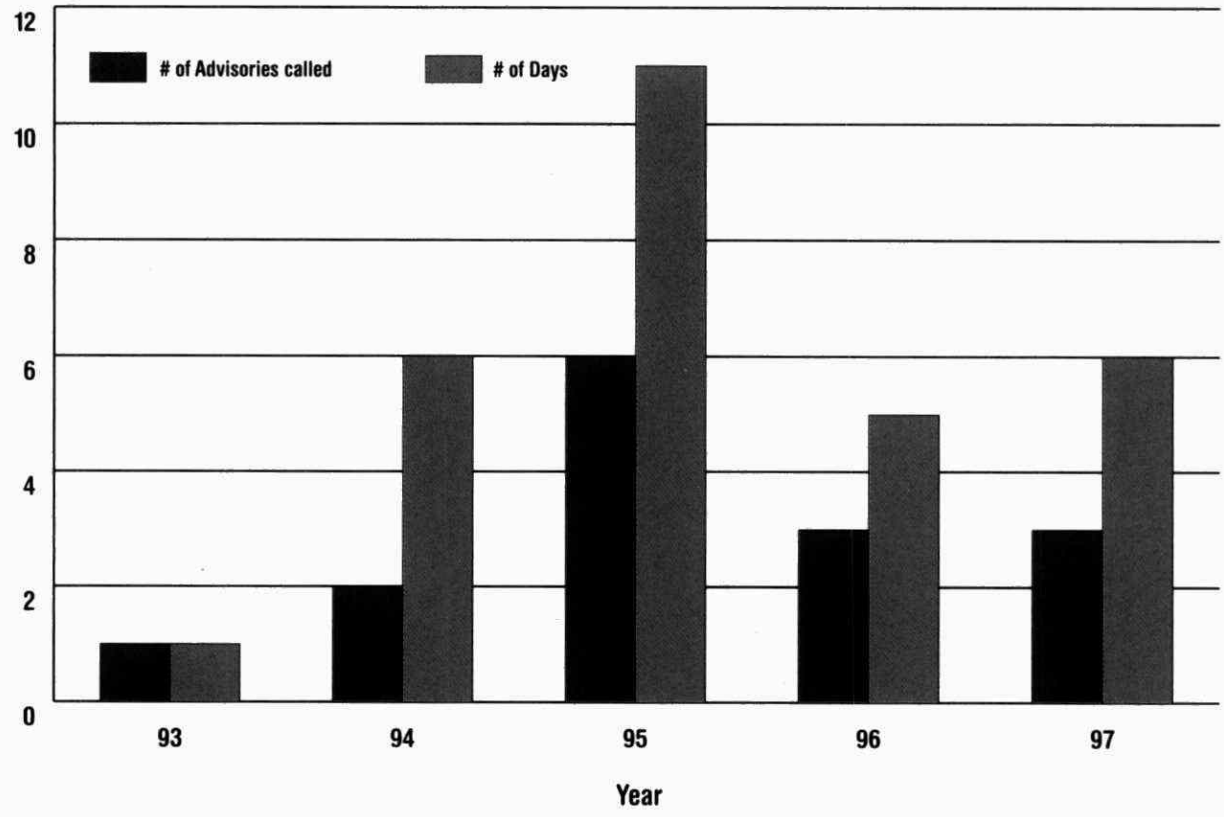
program, which is discussed in Chapter 5.

Air quality advisories are based on provincial forecasts for ground-level ozone. The advisories are issued regionally in the afternoon, the day before expected elevated ozone levels. They encourage people to prevent further deterioration of air quality and outline the effects of air pollution on health and the environment. Air quality advisories are made public via the news media, weather offices and weather radio. They are also available at local ministry offices and through the ministry's Web site: **www.ene.gov.on.ca**.

There are several ways to help reduce ozone (smog) formation. Some of these include limiting driving through car pooling, walking, biking and combining errands; taking public transportation; avoiding excessive idling of vehicles; deferring outdoor chores that use gasoline-powered equipment; postponing the use of oil-based paints and solvents; starting charcoal with an electric starter instead of lighter fluid; and by conserving energy use.

Air quality advisories were issued three times in 1997. One lasted for three days (June 28-30), one for two days (July 13-14) and the third for one day (June 24). Fifteen advisories have been called over the five years 1993 to 1997 (Figure 2.9). In 1993, there was one advisory lasting one day. This was followed by two advisories in 1994 covering a total of six days, six advisories in 1995 covering 11 days, three advisories in 1996 covering five days and three advisories in 1997 covering six days. The number and duration of air quality advisories are highly dependent on weather conditions experienced over southern Ontario each summer between May and September. Regional smog episodes will be discussed in detail in Chapter 6.

Figure 2.9
Summary of Air Quality Advisories (1993-1997)



Chapter 3

Particles in Ontario

Particulate matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air. These particles, which come in a wide range of sizes, originate from many different stationary and mobile sources as well as from natural sources. They may be emitted directly from a source or formed in the atmosphere by the transformation of gaseous emissions. Composition varies with place, season and meteorology. This chapter discusses the ambient monitoring results and trends for the 24-hour (sampling every sixth day) inhalable particles (PM_{10}) network, and the real-time continuous inhalable (PM_{10}) and respirable ($PM_{2.5}$) particle network.

Monitoring for 24-hour inhalable particles (PM_{10})

Since 1989 the ministry has increased monitoring for the smaller fraction (less than 10 microns) of the particulate matter because it is more of a health concern, and because it travels long distances and is linked to trans-boundary pollution. As a result of this growing concern, and as a first step, Ontario

Figure 3.1
Geographical Distribution of 24-Hour PM_{10} Annual Geometric Means at Ambient Sites (1997)

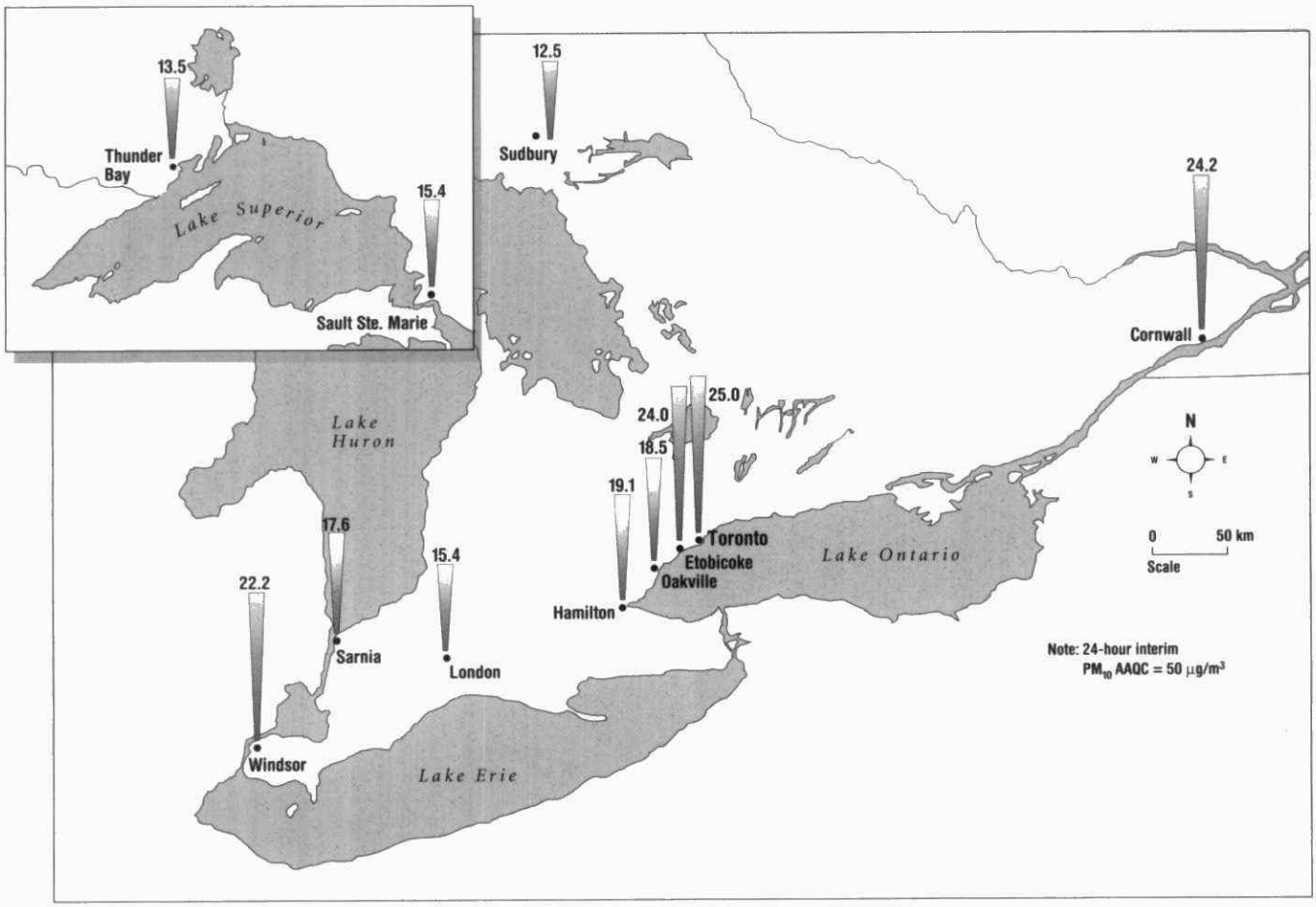
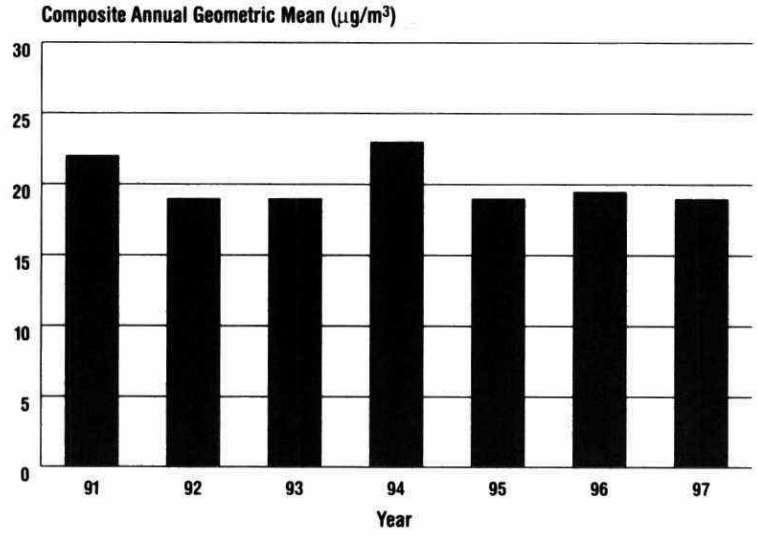


Figure 3.2
Trend for 24-Hour PM_{10} at Ambient Sites (1991-1997)



Note: Data for six ambient urban sites

introduced an interim inhalable particle criterion of 50 µg/m³ on a 24-hour basis in November 1997. This level will be used as a yardstick for assessing the data analyzed in the following discussion.

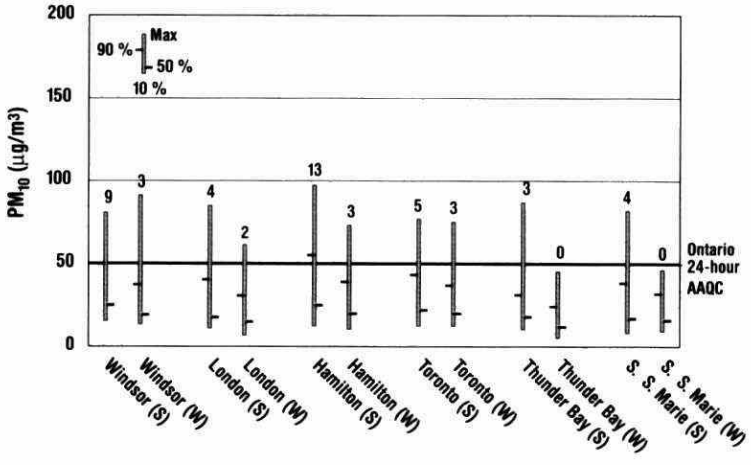
Twenty-four hour inhalable particles (six-day sampling cycle) are measured by a modified hi-volume (hi-vol) sampler outfitted with a size selective inlet to restrict particle size to less than 10 µm. This is the size range of the particle most likely to be inhaled and deposited into the deepest part of the lung (thoracic region). The daily mass of the inhalable particle is computed from the mass of the collected particles and the volume of air sampled. Quartz fibre filters are used as the filter medium for collection. Up to 60 per cent of the total particulate matter may consist of the PM_{10} fraction.

In 1997, 24-hour PM_{10} levels were measured at 24 urban locations. Eleven of the 24 sites monitored for ambient levels and will be discussed here. Results for the remaining 13 sites, which monitored in the vicinity of specific sources, can be found in the separate appendix document.

Figure 3.1 shows the geographical distribution of mean annual PM_{10} levels at ambient sites across Ontario. The highest annual geometric mean (25.0 µg/m³) was recorded at the Toronto downtown site, while the maximum 24-hour concentration (75.0 µg/m³) of PM_{10} was measured at the Cornwall site.

Six of the 11 ambient PM_{10} sites recorded exceedances of the 24-hour interim criterion (50 µg/m³) during 1997. The highest percentages were recorded in Cornwall (6.5), Toronto Downtown (5.8) and Hamilton (5.4).

Figure 3.3
24-Hour PM_{10} Summer vs Winter Statistics at ambient sites (1992-1997)



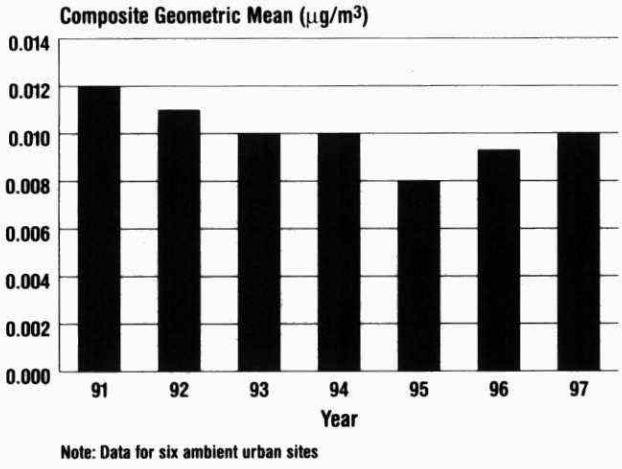
Value at top of bar indicates percentage of time exceeding the Ontario 24-hour interim AAQC
S - denotes summer period; W - denotes winter period

Trends in 24-hour PM_{10}

The provincial trend in 24-hour PM_{10} levels for six ambient urban locations for which data are available over the past seven years is shown in Figure 3.2. No trend is apparent. However, the highest composite geometric mean (22.1 µg/m³) was measured in 1994 and the lowest mean (18.4 µg/m³) in 1997.

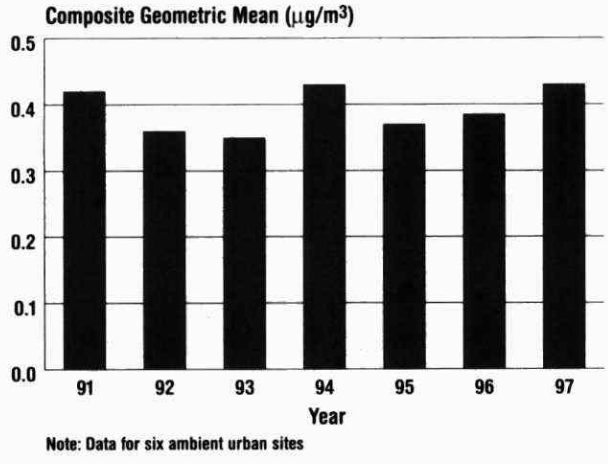
The seasonal trend in 24-hour PM_{10} levels over the six-year period 1992 to 1997 at the six ambient sites is shown in Figure 3.3. General observations based on the graph

Figure 3.4
Trend for Cu in PM_{10} (1991-1997)



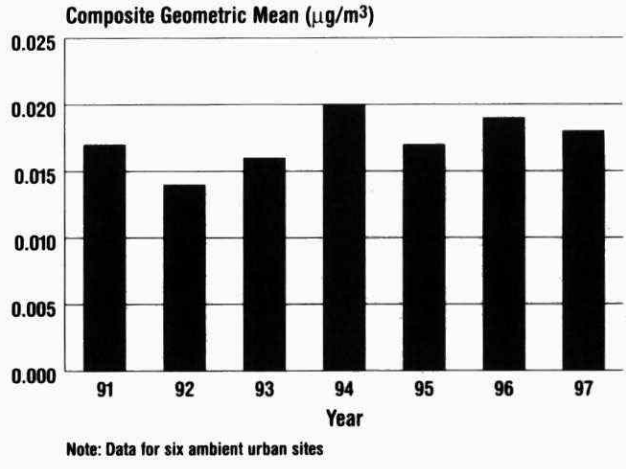
Note: Data for six ambient urban sites

Figure 3.5
Trend for Fe in PM_{10} (1991-1997)



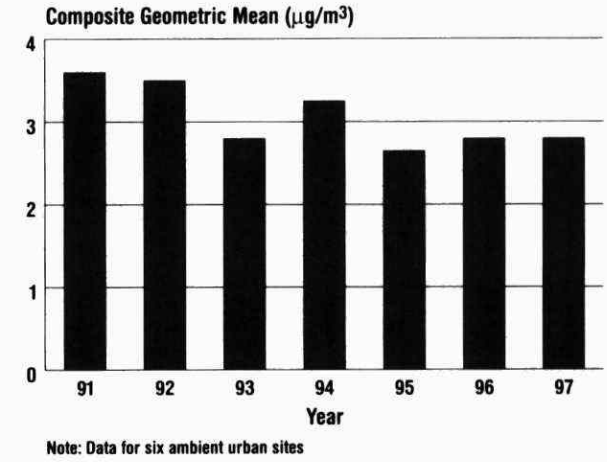
Note: Data for six ambient urban sites

Figure 3.6
Trend for Mn in PM_{10} (1991-1997)



Note: Data for six ambient urban sites

Figure 3.7
Trend for Sulphate in PM_{10} (1991-1997)



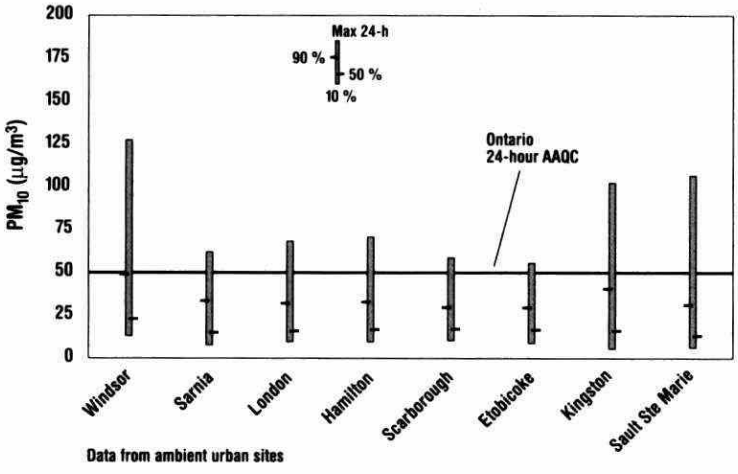
Note: Data for six ambient urban sites

indicate that in southern Ontario PM_{10} exceedance days occur in both summer and winter, with the higher percentage occurring in summer. Windsor and Hamilton show the highest percentage of PM_{10} exceedance days. The majority of exceedance days at the Windsor site are most probably due to the transport of particulate into Ontario from the nearby industrial sources in Detroit. Hamilton, with its escarpment, is influenced by emissions from local industries in the Hamilton harbour area, as well as long-range transport. Over the six-year period there have been no PM_{10} exceedance days in northern Ontario during the winter period.

Monitoring results for selected trace metals and sulphate in PM_{10}

Selected trace metals and sulphate in PM_{10} concentrations were measured at 11 ambient urban locations during 1997. The selected trace metals include iron, copper and manganese. For iron in PM_{10}, the highest mean (0.58 $\mu g/m^3$) was measured at the Toronto Downtown site and the maximum 24-hour concentration (7.40 $\mu g/m^3$) in Sault Ste. Marie. For manganese in PM_{10} the highest mean (0.027

Figure 3.8
Summary Statistics for 24-Hour PM_{10} as Measured by TEOM (1997)



µg/m³) and the maximum 24-hour value (0.290 µg/m³) were recorded at the downtown site in Hamilton. The highest measured copper annual mean (0.032 µg/m³) and the maximum 24-hour value (0.630 µg/m³) were measured in Sudbury during 1997. For sulphate in PM_{10} the highest mean (5.1 µg/m³) and the maximum 24-hour concentration (23.7 µg/m³) were recorded in Cornwall.

Trends for selected metals and sulphate in PM_{10}

The provincial composite trends in copper, iron, manganese and sulphate in 24-hour PM_{10} for six urban locations from 1991 to 1997 are shown in Figures 3.4 to 3.7, respectively. Copper and sulphate show a slight decreasing trend over the seven-year period while iron and manganese are fairly constant over the same period.

Real-time $PM_{10}/PM_{2.5}$ monitoring

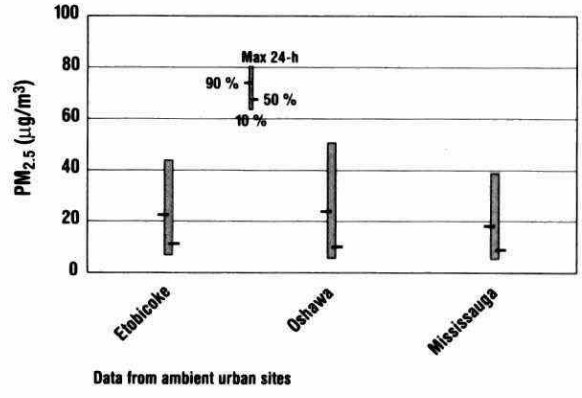
In June of 1995, the ministry installed a state-of-the-art continuous (inhalable and respirable) monitoring network of five sites across the province. Continuous hourly measurements of inhalable and respirable particles are obtained by the Tapered Element Oscillating Microbalance (TEOM) method. The TEOM measures the accumulation of mass on a heated filter attached to the tip of a hollow, tapered, oscillating glass rod. From change in oscillating frequency, direct measurement of mass accumulation on the filter over time is obtained. The $PM_{10}/PM_{2.5}$ monitoring is intended to allow capture of immediate changes in fine particle levels in urban communities, near local industries and in areas affected by trans-boundary sources. The year 1997 marks the second complete year of monitoring fine particles in real-time. Plans are under way to eventually incorporate real-time PM_{10} into Ontario's Air Quality Index system.

Monitoring results for real-time $PM_{10}/PM_{2.5}$

In 1997, monitoring for real-time PM_{10} was conducted at a total of 11 ambient monitoring locations. Eight of the 11 sites recorded sufficient data to be used in this discussion, and their statistics for 1997 are shown in Figure 3.8. The annual mean levels for PM_{10} at the eight ambient sites ranged from a low of 16.8 µg/m³ in Sault Ste. Marie to a maximum of 27.1 µg/m³ in Windsor. The highest 24-hour average (127.3 µg/m³) was recorded in Windsor. It was attributed to local road construction activities. The 24-hour interim PM_{10} criterion of 50 µg/m³ was exceeded on 35 days (9 per cent of the year) in Windsor and on 15 days (4 per cent of the year) in Kingston. Ninety per cent of all measured concentrations at the eight sites were less than 50 µg/m³.

In 1997, continuous monitoring for $PM_{2.5}$ was conducted at a total of 11 ambient monitoring locations. Three of these sites, Etobicoke, Oshawa and Mississauga, recorded sufficient data to be discussed here. The highest annual mean was recorded at Etobicoke (13.0 µg/m³), the highest 24-hour value at Oshawa (50.5 µg/m³) and the maximum one-hour value at Mississauga (76 µg/m³), Figure 3.9.

Figure 3.9
Summary Statistics for 24-Hour $PM_{2.5}$ as Measured by TEOM (1997)



Chapter 4

Other principal contaminants

Pollutants SO_2, NO_2, CO and TRS compounds are discussed in this chapter, as well as their ambient results for 1997 and trends over time. Corresponding annual emission estimate trends are also discussed.

Sulphur Dioxide (SO_2)

Monitoring results for 1997

Monitoring for SO_2 was performed at 29 ambient locations during 1997. The highest annual mean (12.5 ppb), the highest one-hour concentration (543 ppb) and the highest 24-hour concentration (131.1 ppb) were all measured in Windsor during 1997. Two ambient stations, one in Windsor and the other in Sudbury, recorded instances above the SO_2 one-hour criterion of 250 ppb. Windsor had 12 such hours and Sudbury one. There was one instance of exceeding the 24-hour criterion of 100 ppb during 1997. This was recorded at the Windsor College monitor.

Figure 4.1 shows the annual mean SO_2 concentrations across Ontario. Windsor and Sarnia recorded the highest annual levels in 1997. The annual criterion for SO_2 was not exceeded during 1997.

Figure 4.1
Geographical Distribution of SO_2 Annual Mean Concentrations (ppb) at Ambient Sites Across Ontario (1997)

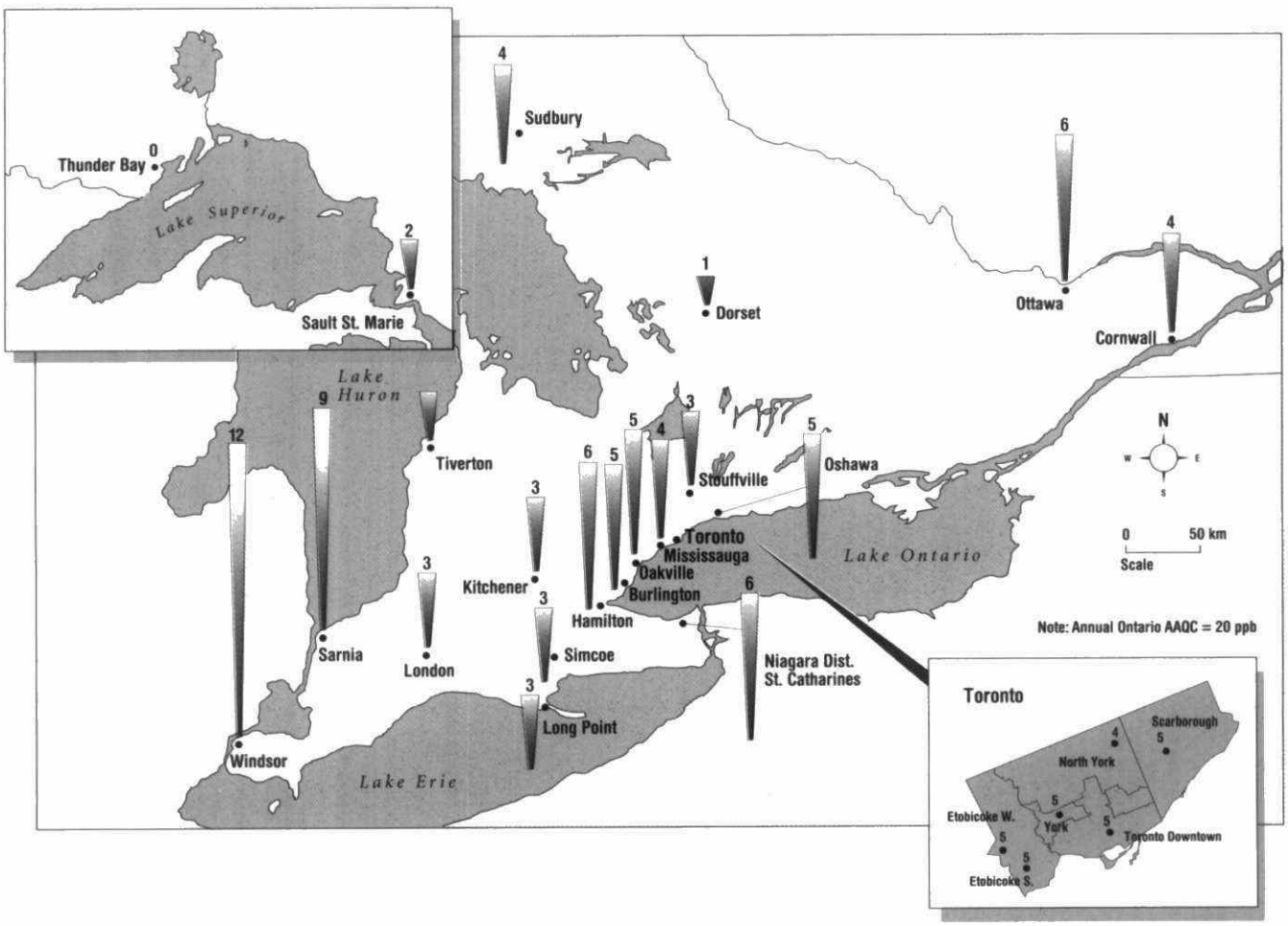
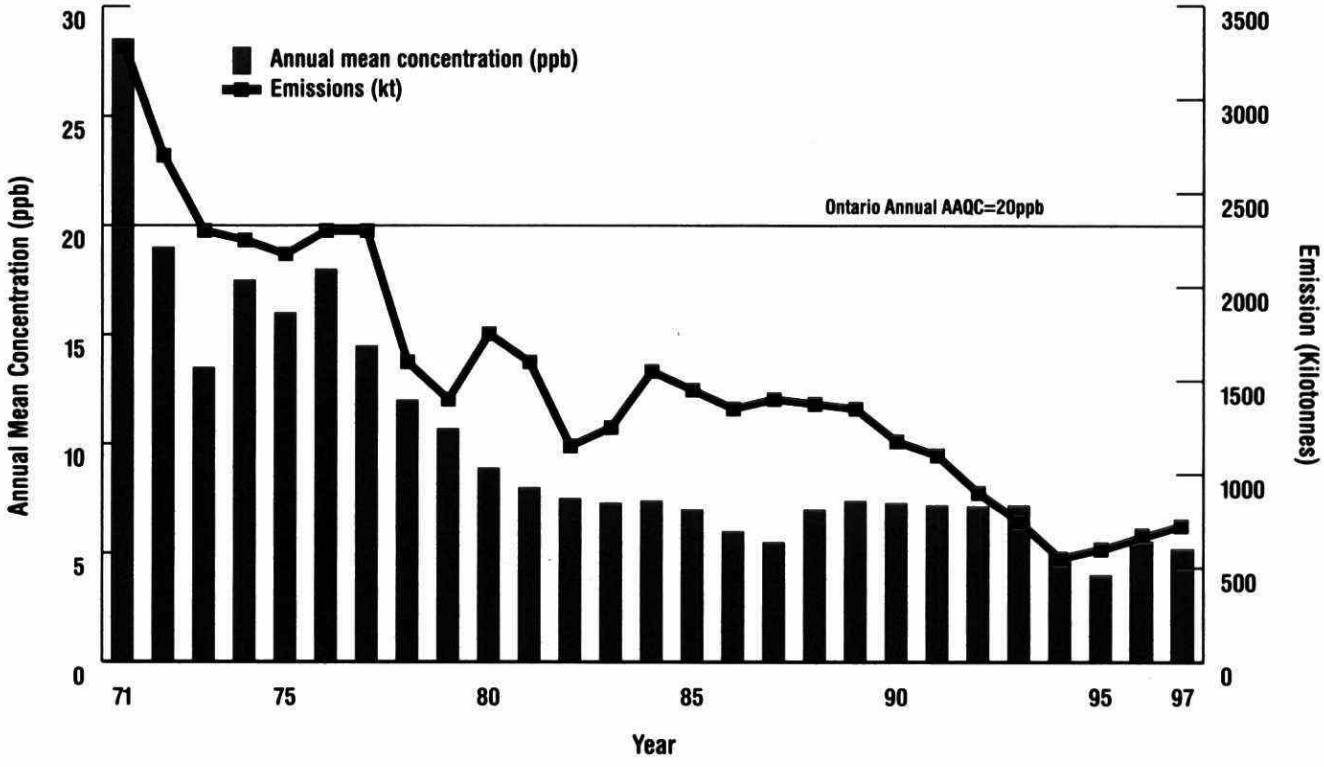
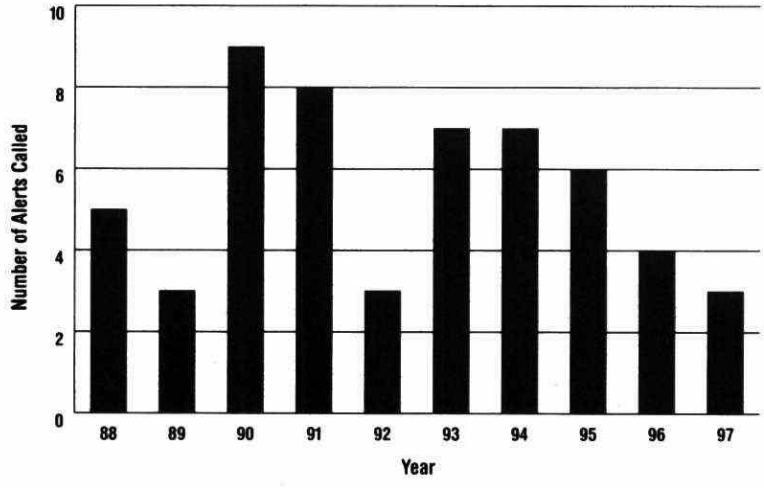


Figure 4.2
Long-Term Trend for SO_2 (1971-1997)



Note: 12 sites operated over 27 years

Figure 4.3
Lambton Industry Meteorological Alert (LIMA) Summary (1988-1997)

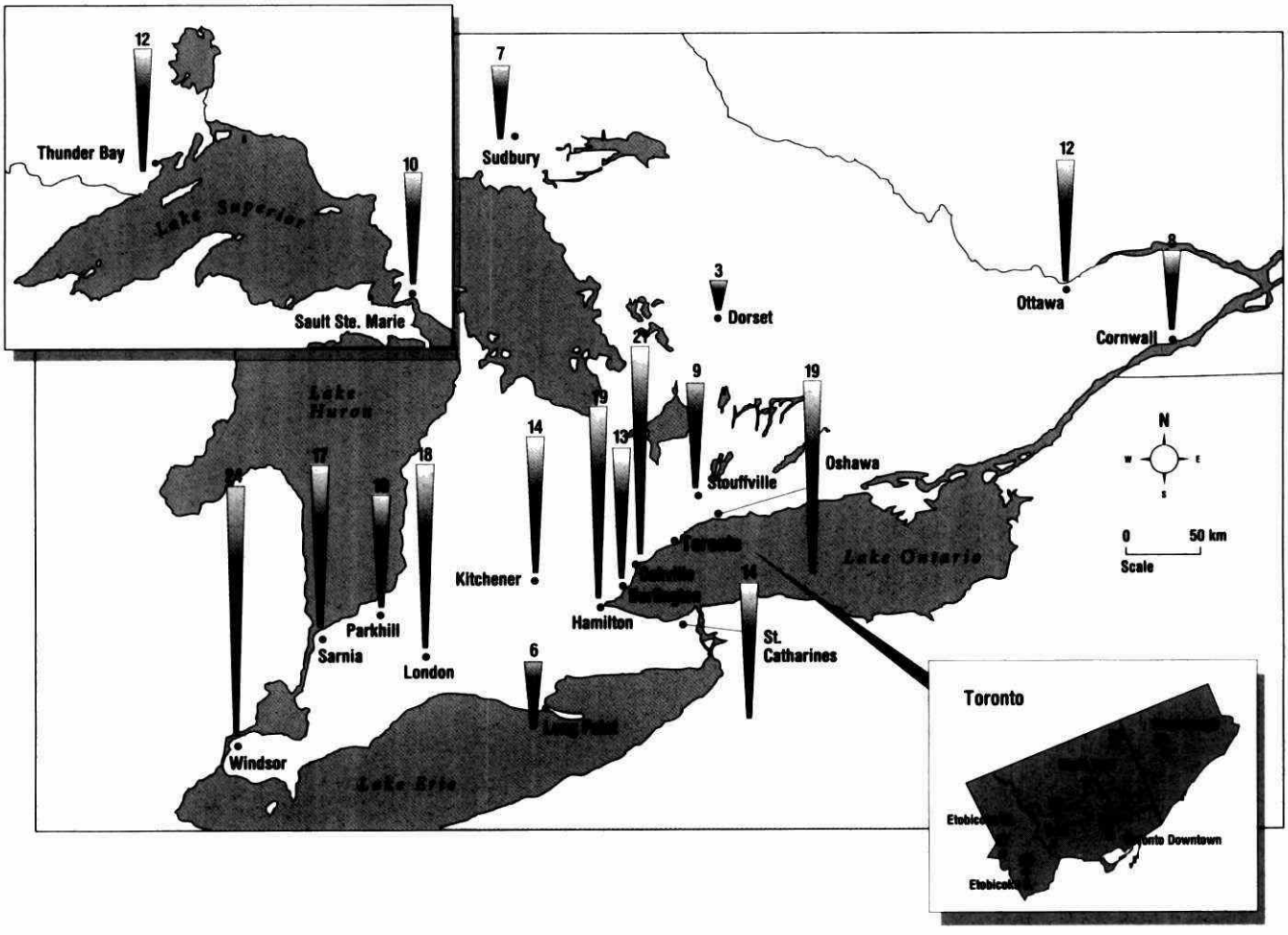


Trends

Over the long term, 1971 to 1997, Ontario's SO_2 emissions decreased 78 per cent, while average SO_2 levels in the province improved by 82 per cent during the same period (Figure 4.2).

Regulations 346 and 350, control orders on smelting operations and the Countdown Acid Rain program have resulted in these significant decreases over the long term. Over the short term, however, SO_2 emissions have shown a slight increasing trend since 1994. This is attributed to an increase in economic activity reflected in the smelting and utility sectors over the same period. The total Ontario SO_2 emissions in 1997 were 718 kilotonnes, up from the 1996 total of 676 kilotonnes, but well below the 1994 countdown limit of 885 kilotonnes.

Figure 4.4
Geographical Distribution of Annual Mean NO_2 Concentrations (ppb) Across Ontario (1997)



Lambton industry meteorological alert (LIMA)

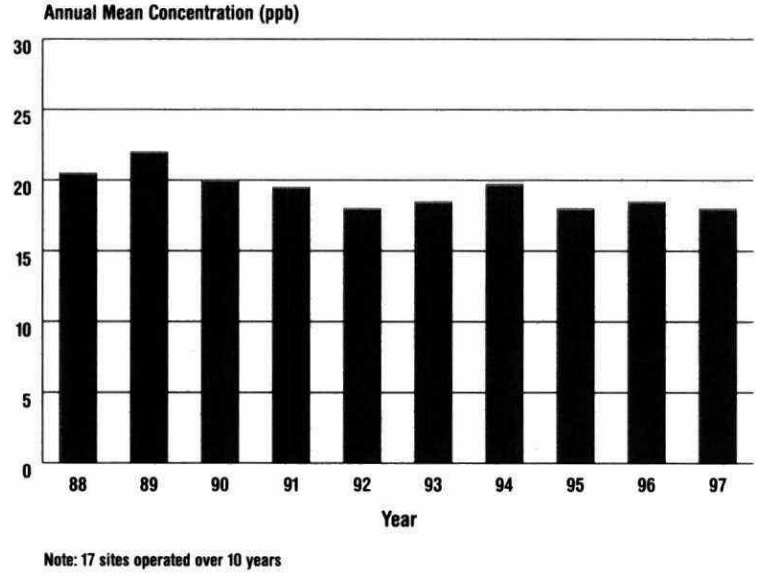
The Lambton industry meteorological alert is covered by the Environmental Protection Act, Regulation 350. Application is limited to that part of the County of Lambton bounded by Lake Huron, the St. Clair River, Highway 80, Moore Township and its continuation through that part of Highway 40, and Lambton County Road 27, which includes Sarnia.

The Minister may declare an alert when the 24-hour running average SO_2 concentration at any station in the LIMA system reaches 70 ppb and meteorological forecasts indicate six hours or more of conditions conducive to elevated SO_2 concentrations. The alert is issued at 70 ppb to prevent levels reaching the Ontario 24-hour SO_2 AAQC (100 ppb).

Two monitoring sites are located in Sarnia (Front Street and Centennial Park), one in Corunna (River Bend) and one in Michigan (Port Huron).

The alert was issued three times in 1997, the longest being for 27 hours from 7 a.m. Feb. 18 to 11 a.m. Feb. 19. All three alerts issued during 1997 were based on SO_2 measurements at the Front Street monitor. LIMA alerts called during the past 10 years are shown in Figure 4.3

Figure 4.5
10-Year Trend for NO_2 Levels (1988-1997)

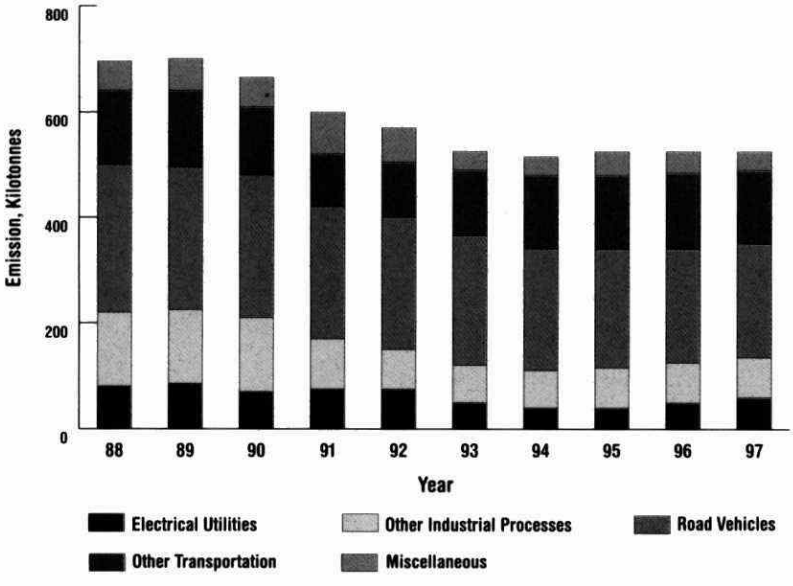


Nitrogen Dioxide (NO_2)

Monitoring results for 1997

Nitrogen dioxide was monitored at 26 ambient locations in 1997. The highest annual mean concentration (31.7 ppb), the maximum one-hour concentration (108 ppb) and the maximum 24-hour concentration (66.2 ppb) were all recorded at the Toronto Downtown site. Typically, highest NO_2 concentrations are recorded in larger urban centres, such as Toronto, Windsor and Hamilton (Figure 4.4). The one-hour criterion of 200 ppb for NO_2 and the 24-hour limit of 100 ppb were not exceeded during 1997.

Figure 4.6
Trend for Ontario NO_x Emission Estimates (1988-1997)



Trends

Provincial average ambient NO_2 levels have remained relatively constant throughout the 1990s. Average concentrations in 1997 were about 10 per cent lower than the levels recorded in 1988 (Figure 4.5). Provincial NO_x emissions decreased 25 per cent during the period 1989 to 1994. This decrease is attributed to reductions in emissions from the industrial and transportation sectors. There has been no change in estimated emissions of NO_x since 1995 (Figure 4.6).

Figure 4.7
Geographical Distribution of 1-Hour Maximum CO Concentrations (ppm) Across Ontario (1997)

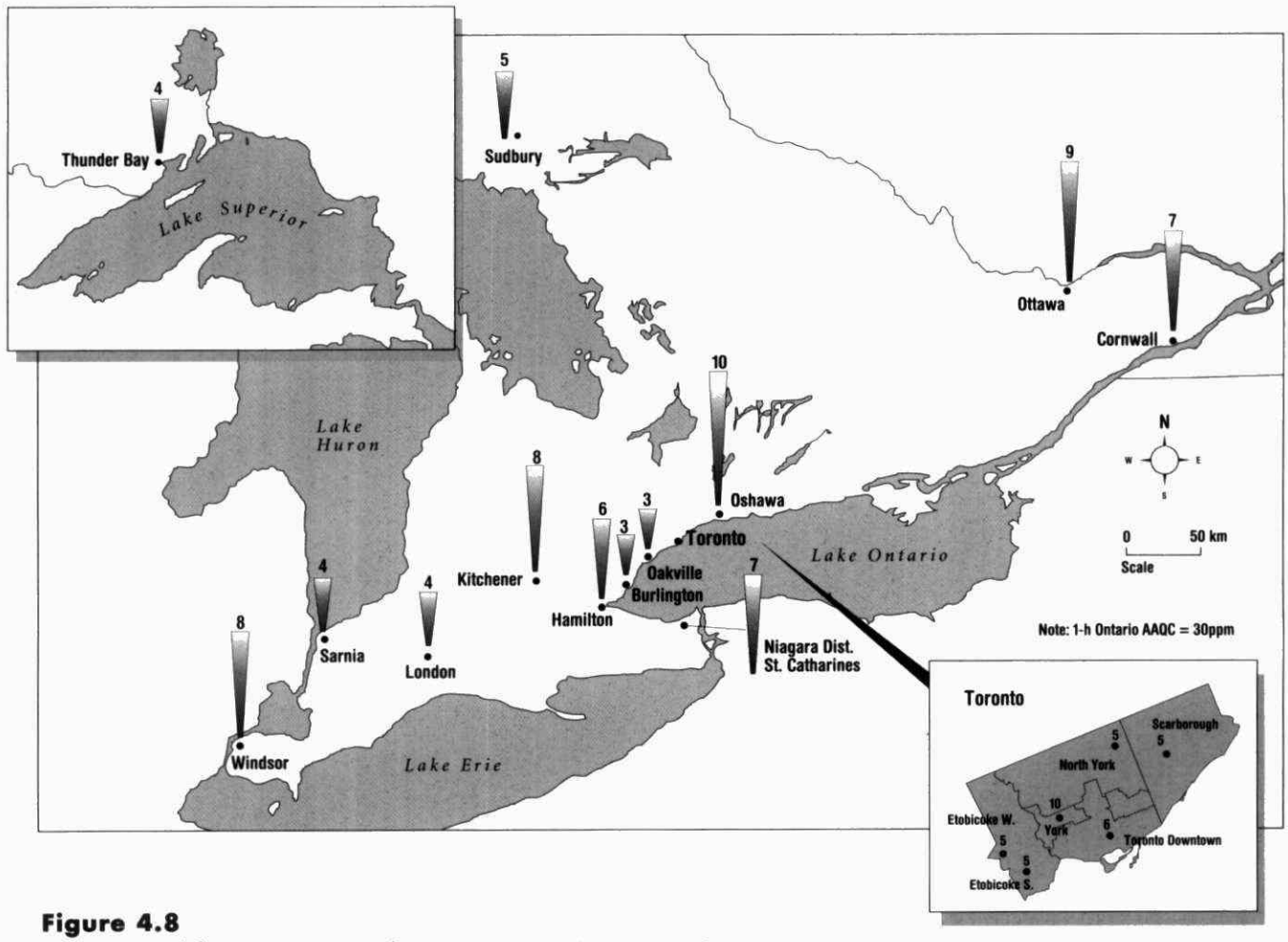
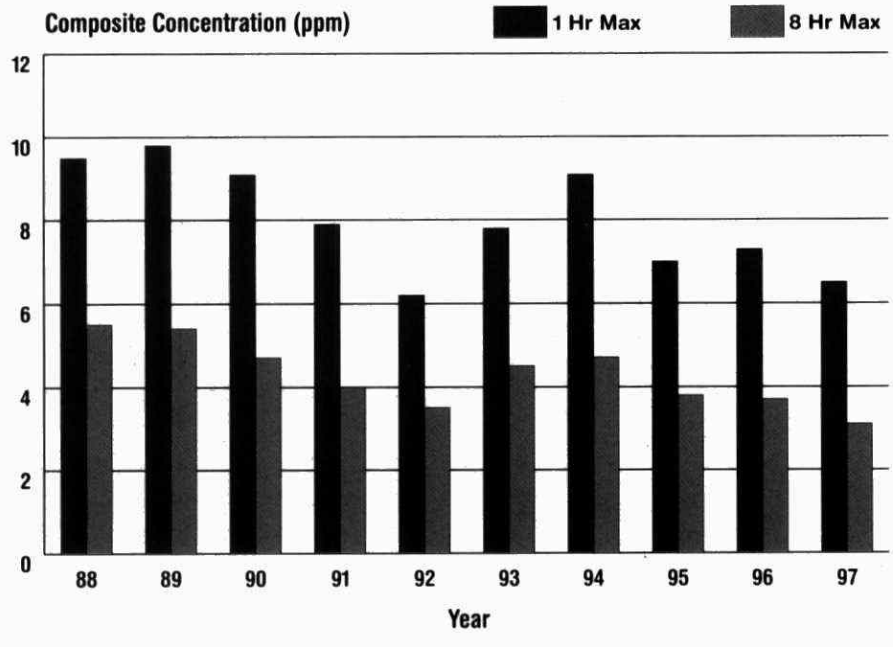
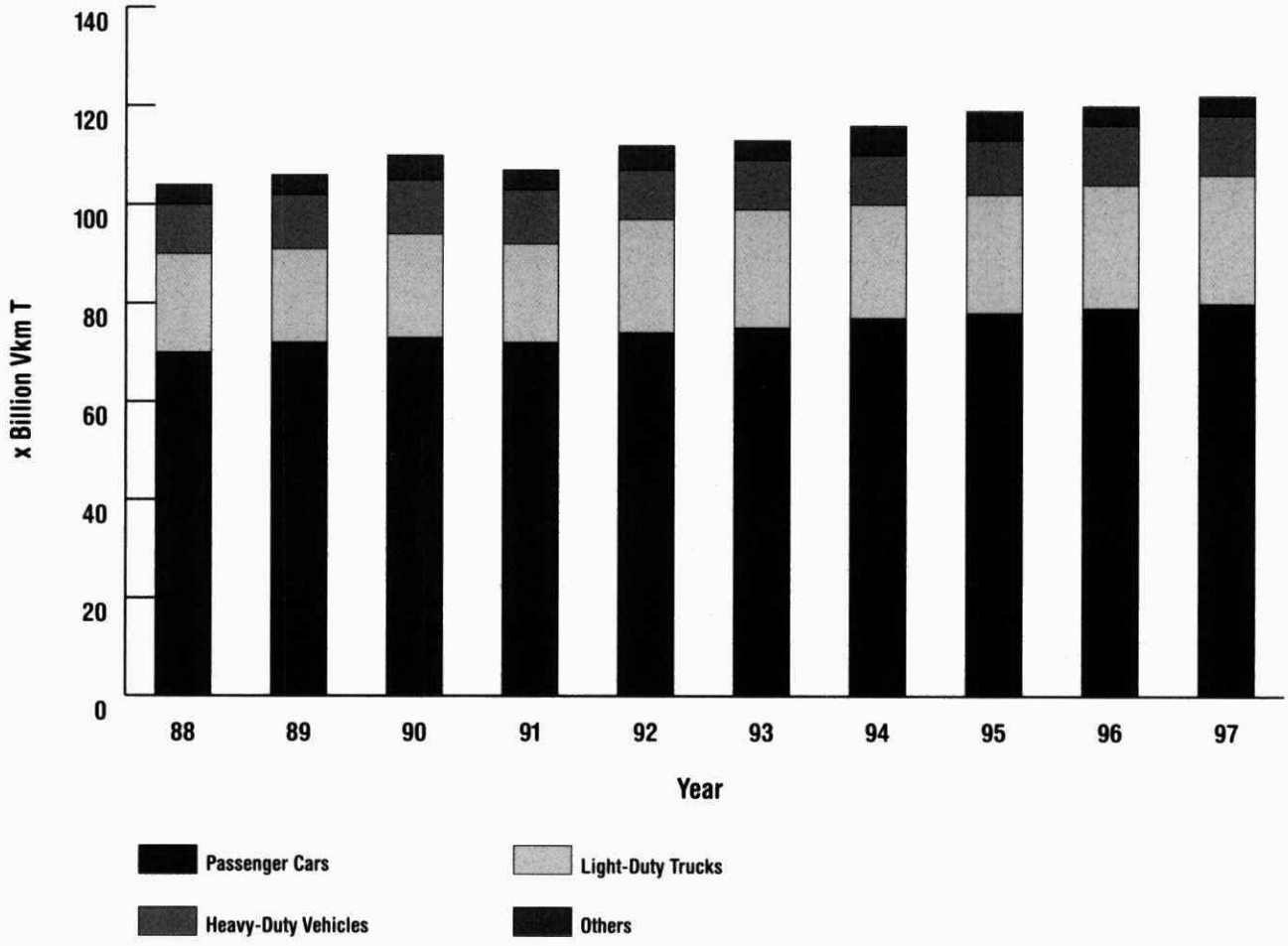


Figure 4.8
10-Year Trend for CO 1-Hour and 8-Hour Maxima (1988-1997)



Note: 1-Hr AAQC = 30ppm; 8-Hr AAQC = 13ppm

Figure 4.9
Trend for Ontario Vehicle-Kilometres Travelled (1988-1997)



Carbon Monoxide (CO)

Monitoring results for 1996

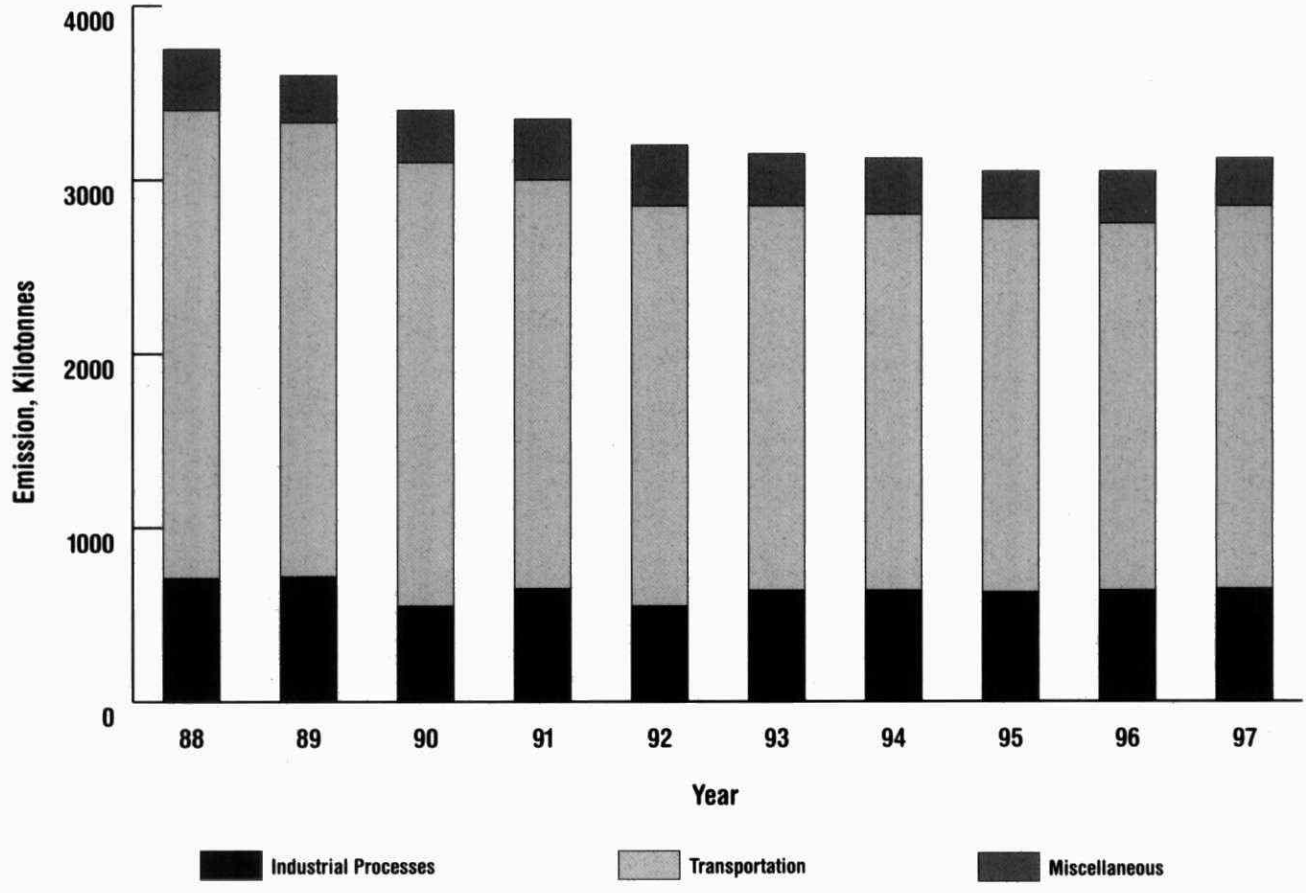
Carbon monoxide was monitored at 20 ambient locations in 1997. The highest annual mean (1.2 parts per million) was recorded at the Toronto Downtown site. The highest eight-hour measured value (6.1 ppm) was recorded at Oshawa while the highest one-hour concentration (10 ppm) was measured at the York monitor in Toronto and in Oshawa. Highest CO levels are recorded typically in larger urban centres as a result of vehicle emissions (Figure 4.7). There were no instances of exceeding the one-hour or eight-hour AAQC in 1997. The CO one-hour (30 ppm) and eight-hour (13 ppm) ambient air quality criteria (AAQC) have not been exceeded since 1991.

Trends

The trends in provincial averaged one-hour and eight-hour maximum CO concentrations are shown in Figure 4.8 for the period 1988 to 1997. Over this 10-year period, ambient CO concentrations as measured by the composite average of the one- and eight-hour maximums were reduced by 32 and 38 per cent, respectively. These reductions in ambient CO levels occurred despite a 17 per cent increase in vehicle-kilometres travelled over the same 10-year period (Figure 4.9).

Provincial CO emissions show a decline since 1989 due to the new vehicle emission standards (Figure 4.10). The transportation sector accounts for 67 per cent of the provincial total CO emissions. Since 1988, emissions from this sector have decreased by about 17 per cent.

Figure 4.10
Trend for Ontario CO Emission Estimates (1988-1997)



Total Reduced Sulphur (TRS) Compounds

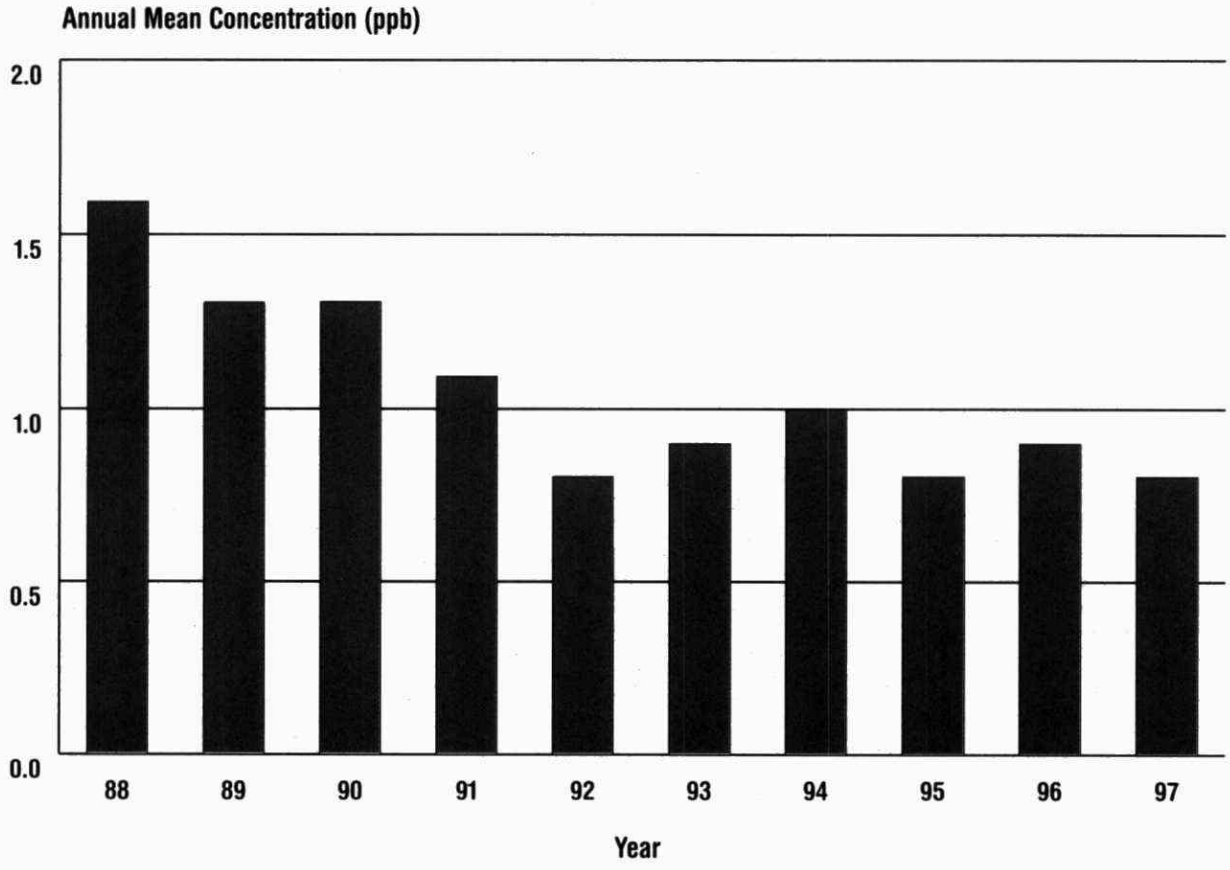
Monitoring results for 1997

Monitoring for TRS compounds was carried out at 12 ambient locations in 1997. The highest annual mean concentration (2.0 ppb) was recorded at the Cornwall location, while the highest one-hour concentration (129.0 ppb) was recorded in Fort Frances. Elevated TRS levels are mainly attributed to the pulp and paper industry.

Trends

The trend in provincial composite averaged TRS levels at ambient monitoring sites is shown in Figure 4.11. A decreasing trend over the 10-year period is evident. Mean average ambient TRS levels in 1997 are 50 per cent lower than they were in 1988. This decrease is mainly attributed to abatement and regulatory action taken by the ministry over the years.

Figure 4.11
10-Year Trend for Annual Mean TRS Levels (ppb) at Ambient Sites (1988-1997)



Note: 12 sites operated over 10 years

Chapter 5

Air quality indices

Air Quality Index (AQI)

The Ministry of the Environment operates an extensive network of air quality monitoring sites across the province. In 1997, the AQI network consisted of 27 sites in 24 urban centres. Figure 5.1 shows the location of the AQI sites.

This network, in place since 1988, provides the public with real-time air quality information across the province. The AQI is based on pollutants that have adverse effects on human health and the environment: sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2), total reduced sulphur (TRS) compounds, carbon monoxide (CO) and suspended particles (SP). At the end of each hour the concentration of each pollutant measured at a particular site is converted into a number that ranges from zero upwards. The calculated number for each pollutant is called a sub-index.

The highest sub-index at the given hour becomes the AQI. The index increases as the air

Figure 5.1
Geographical Distribution of the Number of Hours AQI>31 Across Ontario (1997)

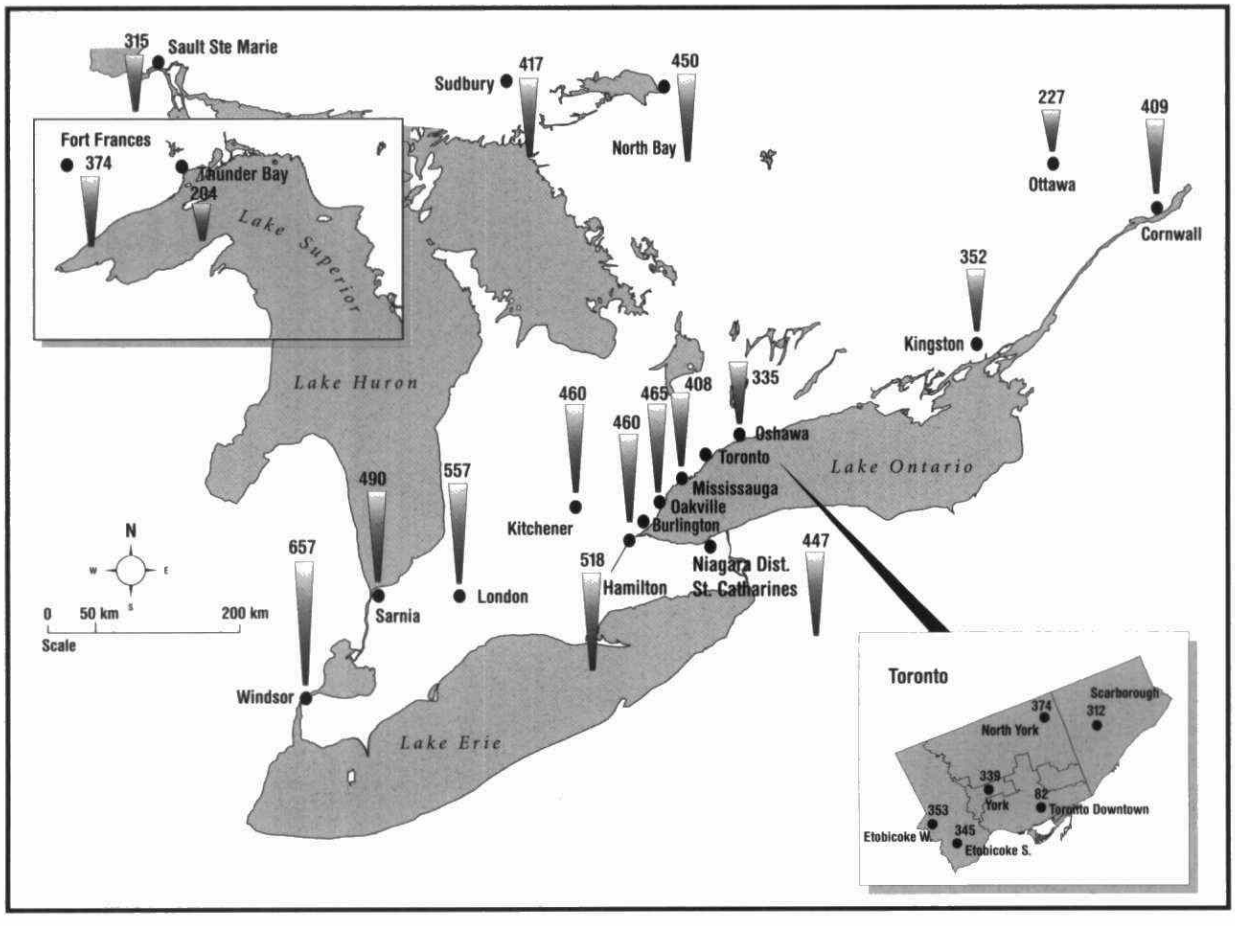


Table 5.1
Air Quality Index Pollutants and their Impact

Index	Category	Carbon Monoxide (CO)	Nitrogen Dioxide (NO_2)	Ozone (O_3)	Sulphur Dioxide (SO_2)	Suspended Particles (SP)	SO_2 + SP (As measured by the API)	Total Reduced Sulphur (TRS)
0-15	Very good	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
16-31	Good	No known harmful effects	Slight odour	No known harmful effects	Damages some vegetation in combination with ozone	No known harmful effects	No known harmful effects	Slight odour
32-49	Moderate	Blood chemistry changes, but no noticeable impairment	Odour	Respiratory irritation in sensitive people during vigorous exercise; people with heart/ lung disorders at some risk; damages very sensitive plants	Damages some vegetation	Some decrease in visibility	Damages vegetation (i.e. tomatoes, white beans due to sulphur dioxide	Odour
50-99	Poor	Increased symptoms in smokers with heart disease	Air smells and looks brown. Some increase in bronchial reactivity in people with asthma	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/ lung disorders at greater risk; damage to some plants	Odourous; increasing vegetation damage	Decreased visibility; soiling evident	Increased symptoms for people with chronic lung disease	Strong odour
100-over	Very poor	Increasing symptoms in non- smokers with heart diseases; blurred vision; some clumsiness	Increasing sensitivity for people with asthma and bronchitis	Serious respiratory effects, even during light physical activity; people with heart/ lung disorders at high risk; more vegetation damage	Increasing sensitivity for people with asthma and bronchitis	Increasing sensitivity for people with asthma and bronchitis	Significant effects for people with asthma and bronchitis	Severe odour, some may experience nausea and headaches

quality deteriorates. The index values, corresponding categories and potential health and environmental effects are shown in Table 5.1.

If the AQI value is in the range from 32 to 49 there may be some adverse health effects on very sensitive people. An index value in the 50 to 99 range may have adverse effects on the most sensitive of the human or animal populations, or may cause significant damage to vegetation and property. An AQI value of 100 or more may cause adverse effects to the health of a large sector of those exposed.

The Air Pollution Index (API) is also a sub-index of the AQI. The basis of an alert and control system to warn of deteriorating air quality, the API is derived from 24-hour running averages of SO_2 and SP.

The Air Quality Office at the Environmental Monitoring and Reporting Branch continually obtains data from the 27 AQI sites .

Computed air quality indices and AQI forecasts are released to the public and news media at set intervals. The public can access the index values by calling the ministry's automatic telephone answering device (English recording: local calls 416-246-0411 or 1-800-387-7768. French recording: 1-800-221-8852). The AQI can also be obtained from the ministry's Web site: **www.ene.gov.on.ca**.

AQI forecasts based on the meteorological conditions and pollutant trends are provided daily.

Table 5.2
Air Quality Index Summary (1997)

			Number of Hours AQI in Range					# of hrs Pollutant Responsible For AQI >31							# of days at least 1hr
			V-Good	Good	Mod.	Poor	V-Poor								
Stn ID	City	Valid hours	0-15	16-31	32-49	50-99	100+	SP	O_3	TRS	SO_2	API	CO	NO_2	>31
12008	Windsor U.	8760	5585	2623	496	56	0	6	546	X	0	0	0	0	92
12016	Windsor C.	8752	5433	2662	590	67	0	12	431	205	8	1	X	X	146
14064	Sarnia	8749	4302	3957	474	16	0	0	486	4	0	0	0	0	78
15025	London	8753	5126	3070	509	48	0	0	557	X	0	0	0	0	81
26060	Kitchener	8736	4691	3585	440	20	0	2	458	X	0	0	0	0	69
27067	St Catharines	8465	5196	2822	431	16	0	1	446	X	0	0	0	0	65
29000	Hamilton Dt.	8760	5525	2845	373	17	0	29	336	25	0	0	0	0	71
29114	Hamilton Mtn.	8756	4900	3338	488	30	0	4	499	15	0	0	X	0	76
29118	Hamilton W.	8760	5569	2834	339	18	0	1	346	10	0	0	0	0	56
31303	Toronto Dt.	8728	7225	1421	79	3	0	1	81	X	0	0	0	0	22
33003	Scarborough	8573	5933	2328	281	31	0	0	312	X	0	0	0	0	55
34020	North York	8736	5023	3339	348	26	0	1	373	X	0	0	0	0	63
35003	Etobicoke W.	8723	5594	2776	324	29	0	8	345	X	0	0	0	0	61
35033	Etobicoke S.	8744	6085	2314	304	41	0	19	326	X	0	0	0	0	64
36030	York	8678	5616	2723	306	33	0	16	323	X	0	0	0	0	77
44008	Burlington	8689	4963	3266	446	14	0	2	458	X	0	0	0	0	79
44015	Oakville	8760	5206	3089	438	27	0	5	460	0	0	0	0	0	75
45025	Oshawa	8752	4634	3783	296	39	0	3	332	X	0	0	0	0	62
46110	Mississauga	8496	5173	2915	380	28	0	10	398	X	0	0	0	0	70
51001	Ottawa	8760	5148	3385	222	5	0	0	227	X	0	0	0	0	38
52020	Kingston	8753	5327	3074	323	29	0	7	345	X	X	X	X	X	58
56051	Cornwall	8760	4638	3713	387	22	0	0	373	36	0	0	0	0	75
62200	Fort Frances	8759	2932	5453	330	44	0	0	232	142	X	X	X	X	90
63200	Thunder Bay	8671	4041	4426	204	0	0	0	203	1	0	0	0	0	30
71068	Sault Ste Marie	8760	3966	4479	311	4	0	2	276	37	0	0	0	0	58
75010	North Bay	8741	3494	4797	420	30	0	0	450	X	X	X	X	X	70
77203	Sudbury	8749	3199	5133	384	33	0	0	416	0	1	0	0	0	60

X - pollutant not measured

Summary Air Quality Index levels (1997)

The frequency distribution of hourly AQI, according to descriptive category and to pollutant responsible for AQI above 31, is shown for the 27 monitoring locations in Table 5.2. The data are presented for the AQI stations. Air quality was most often in the "good/very good" categories at all AQI sites across the province. Based on the cumulative total number of monitored hours (235,323) at the 27 sites, on average, good to very good air quality was reported 95.5 per cent of the time. Good to very good air quality readings ranged from 92.5 per cent at Windsor College to 99.1 per cent at Toronto Downtown.

The geographical distribution of the number of hours of AQI > 31 is shown in Figure 5.1. At all AQI sites ozone was the most frequent cause of index readings exceeding 31 and ranged from 62 per cent at Fort Frances to100 per cent at London. There were 10,669 hours (4.5 per cent of hours monitored) of moderate to poor air quality recorded at the 27 sites in 1997. Although ozone was the most frequent cause of index readings over 31, Windsor College recorded

Table 5.3
Air Quality Index Summary Statistics by Regions (1997)

Regions	% Time AQI in Range				% Time Pollutant Responsible For AQI >31						
	V-Good	Good	Mod.	Poor	SP	O_3	TRS	SO_2	API	CO	NO_2
Southwest	58.4	35.2	5.9	0.5	0.8	89.5	9.3	0.4	0.0	0.0	0.0
West Central	59.5	35.5	4.8	0.2	1.7	96.0	2.3	0.0	0.0	0.0	0.0
GTA	63.8	32.2	3.7	0.3	1.9	98.1	0.0	0.0	0.0	0.0	0.0
Eastern	57.5	38.7	3.6	0.2	0.7	95.7	3.6	0.0	0.0	0.0	0.0
Northern	40.4	55.6	3.8	0.2	0.1	89.6	10.3	0.0	0.0	0.0	0.0

Figure 5.2
AQI Summary by Region (1997)

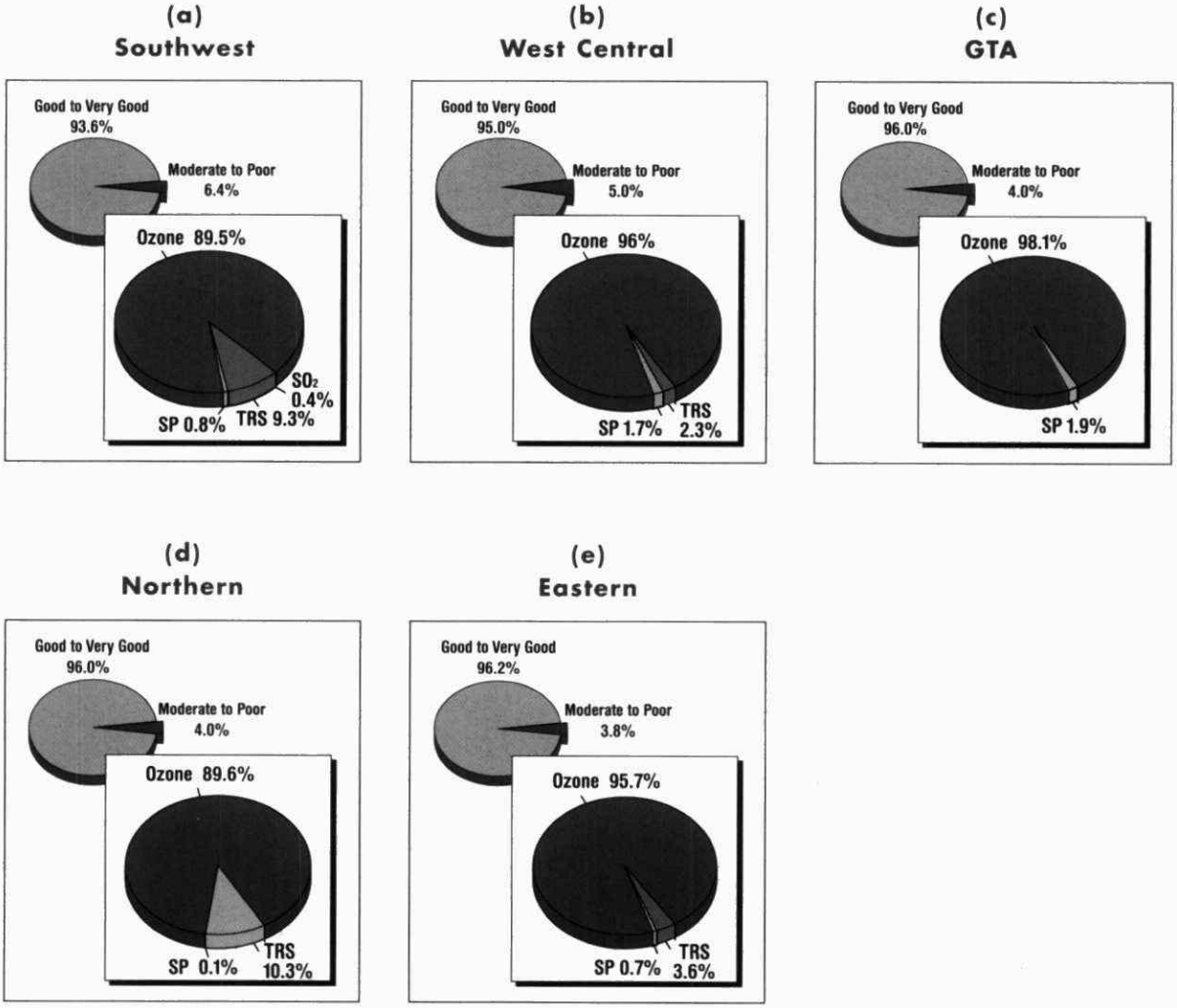
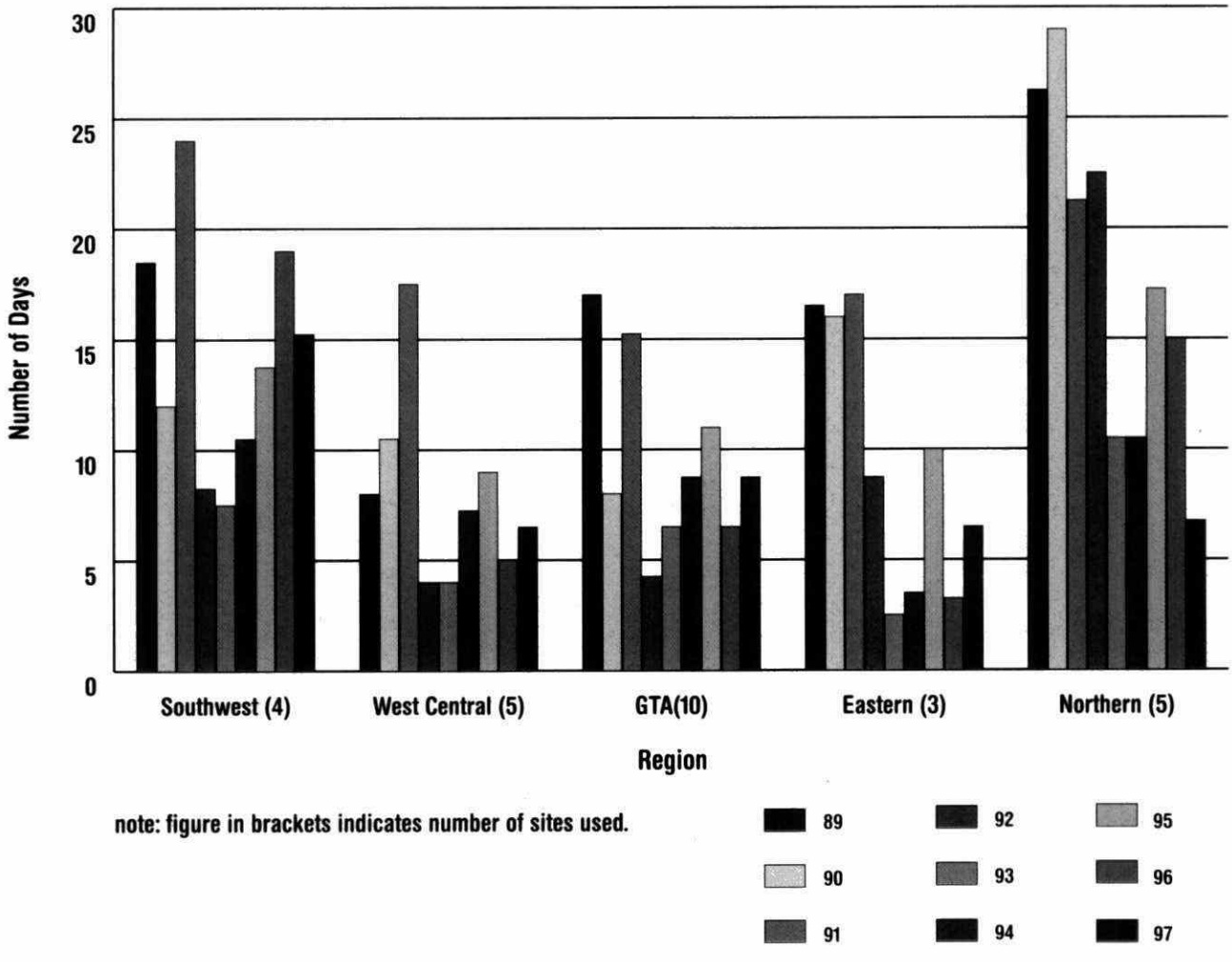


Figure 5.3
Trend of the Average Number of Days AQI>49 for Various Regions of Ontario (1989-1997)



205 hours of index readings greater than 31 due to TRS compounds. This is the first year since the inception of the AQI system in 1998 that Fort Frances did not record the highest number of hours of AQI greater than 31 due to TRS compounds (142 hrs).

Windsor College also recorded eight hours of moderate air quality due to SO_2 and one hour due to the API. As in previous years no hours of very poor air quality were recorded at the AQI sites during 1997.

The number of days during which the AQI at each site was greater than 31 for at least one hour is also shown in Table 5.2. The number of days varied from 23 at Toronto Downtown to 146 at Windsor College. Only two of the 23 days at Toronto Downtown recorded index values greater than 49. There were no days with poor air quality (AQI > 49) recorded at the Thunder Bay site.

Figures 5.2a to 5.2e show pie diagrams for very good to good and moderate to poor air quality for each region. Each pie on the left shows total percentages and the corresponding pie on the right breaks down the slice that indicates moderate to poor air quality into percentages of pollutants that pushed the AQI above 31. The pie diagrams show AQI in

very good to good categories ranging from 93.6 per cent in the southwest region to 96.2 per cent in the eastern region.

Summary statistics for each region are presented in Table 5.3 showing the percentage time that the AQI was in each category and also the percentage time each pollutant caused the AQI to be greater than 31. The table shows that in 1997 the southwest region had the highest percentage of time with moderate to poor air quality. The northern region had the lowest percentage of very good air quality but at the same time recorded the highest percentage of good air quality (greater than 55 per cent). This is due to the higher number of ozone values in the good category during the winter and spring seasons in northern Ontario. In the southwest region there was a fourfold increase in index values greater than 31 due to TRS compound from 1996 to 1997. This was due to TRS recorded at Windsor College and reflects the influence of Michigan sources on the air quality measured at this site. This is also true for SO_2 at this site. On the other hand, TRS levels in the moderate/poor categories decreased markedly in the northern region due to a reduction in the levels at Fort Frances.

Regional AQI trends (1989-1997)

A nine-year trend (1989-1997) for the number of hours that the AQI was greater than 49 (in the poor category) by region is shown in Figure 5.3. The average number of AQI hours greater than 49 at sites in all of the regions showed a continuous decrease from 1989 to 1993. From 1993 onwards all regions except the northern region show an increase in the average number of days per year with AQI greater than 49. The greatest increase was in the southwest region, which is very close to the U.S. sources of emissions that react to produce ozone. The air quality is affected by ozone transported by wind into the area. The west central region and the Greater Toronto Area showed a slight increasing trend, with the Greater Toronto Area showing a larger increase. The northern region showed no trend after 1993, with a large decrease in AQI days greater than 49 in 1997. In northern Ontario there has been a significant reduction of TRS levels at Fort Frances.

Air Pollution Index (1997)

One hour of air quality greater than 31 due to API (an API of 32) was recorded at Windsor College during 1997. This value was recorded on July 18, 1997, when concentrations of TRS compounds, SO_2 and suspended particulate matter were elevated. Winds were westerly and thus the Windsor College site was monitoring emissions from sources in Michigan.

Chapter 6

Regional smog episodes

The generation, build-up and dissipation of air pollutants over eastern North America have been studied by numerous researchers over the past decades. Such studies have shown that the air pollutant life-cycle is strongly influenced by synoptic-scale weather systems.

In particular, pollutants associated with various issues (e.g., acidic species, ground-level ozone and its precursors, fine particles and persistent organic pollutants) are often transported by large-scale weather systems up to thousands of kilometres from their point of origin before being deposited or impacting on receptors. Long-range transport and trans-boundary flow of air pollutants thus have a significant role in air quality considerations on a regional scale.

For southern Ontario, this is particularly evident for ozone during late spring and summer. Elevated ozone is then primarily a component of photochemical smog in which nitrogen oxides and hydrocarbons (volatile organic compounds), precursors of ozone, react in the air in the presence of

Figure 6.1
Generalized Synoptic Weather Pattern Over Southern Ontario Conducive to Elevated Pollutant Levels

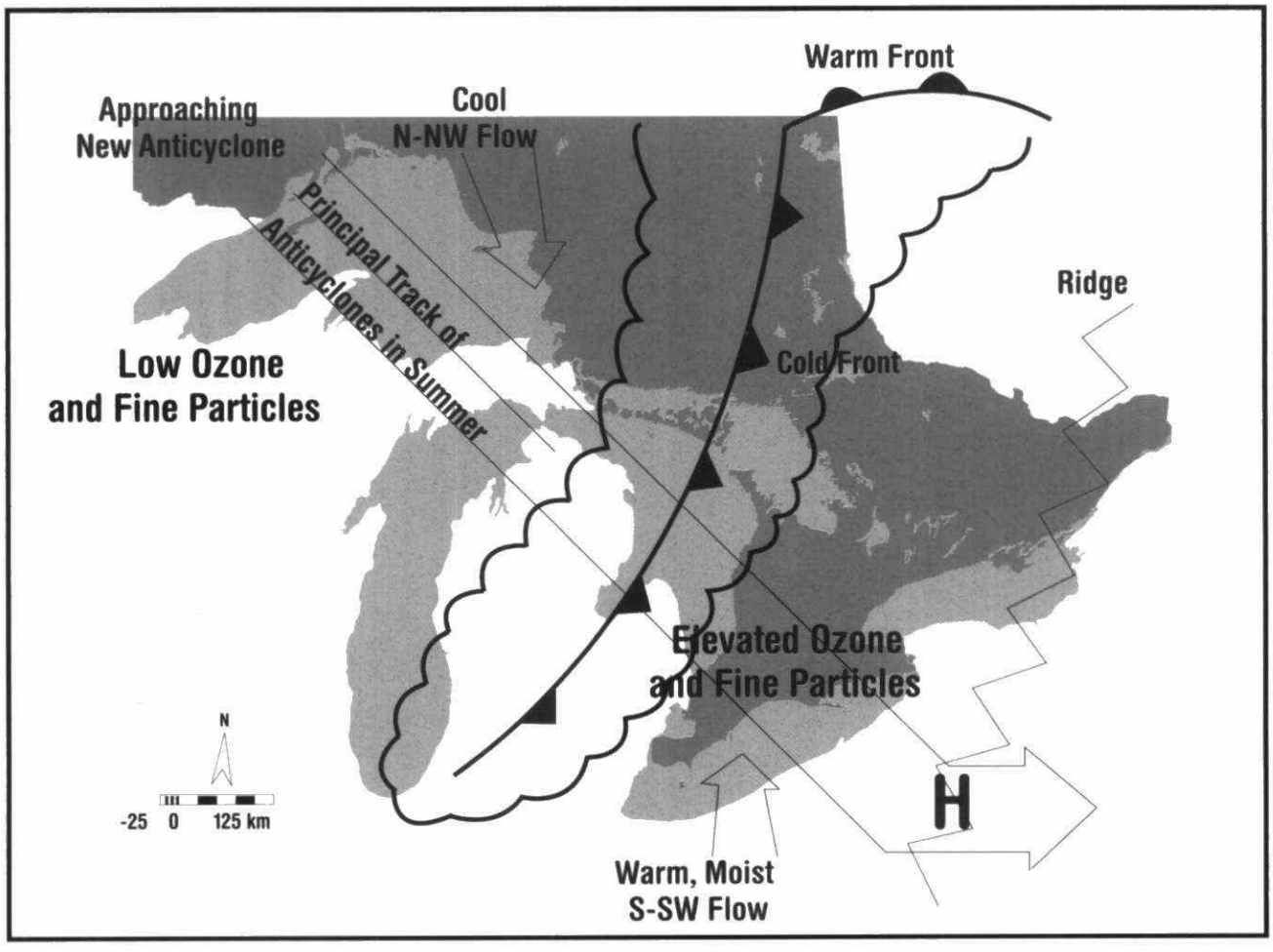
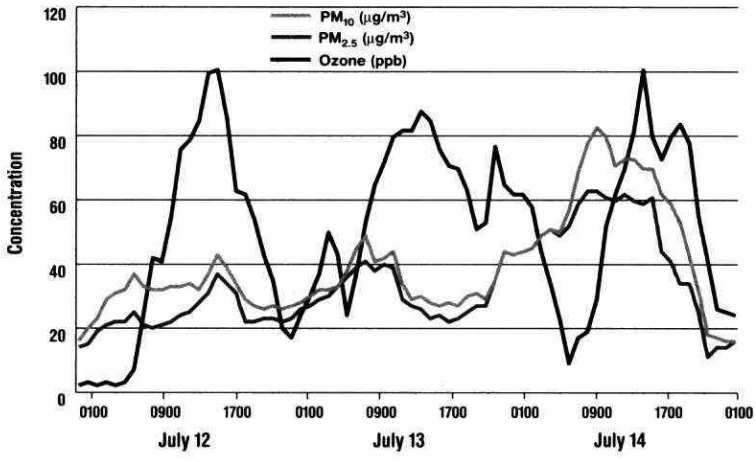


Figure 6.2
PM_{10}, $PM_{2.5}$ & Ozone Concentrations for July 12-14, 1997 at Etobicoke South



sunlight. The ozone tends to be formed downwind of precursor sources and is thus capable of travelling long distances through the atmosphere. As a result, ozone is often the manifestation of long-range transport and trans-boundary flow of air pollution.

Episodes of elevated ozone at ground level usually occur between May and September, and are associated with high pressure weather systems that typically move out of central Canada into the U.S. midwest or the Great Lakes area and then eastward to the Atlantic coast. The frequency of these episodes varies from year to year and depends on large-scale weather patterns and meteorological factors.

Episodes in southern Ontario are often a part of a regional condition that prevails over much of northeastern North America. For southern Ontario, it is a significant trans-boundary problem, since elevated levels are often due to weather patterns that affect the lower Great Lakes region, resulting in the long-range transport of ozone and its precursors from neighbouring U.S. industrial states. Ontario often shares a common airshed with several neighbouring states, hence emissions in one source area can affect air quality in the whole airshed.

Figure 6.1 illustrates a generalized synoptic weather pattern over southern Ontario during high smog conditions. The back portion of a slow-moving high pressure system generally has winds with a southerly component that have travelled over major precursor source areas located in the midwest and eastern United States.

As the high pressure moves west to east, precursors are emitted into the front of the system and circulate to the rear over a period of two to six days, depending on the wind speed. This results in the accumulation of a number of pollutants (both primary and secondary species) in the air mass. As a result, south to southwesterly flow on the rear side of a high pressure cell provides favourable conditions for transport of pollution and is conducive to episodes of fine particles and ozone pollution simultaneously over southern Ontario.

An example of such an episode in 1997 is shown in Figure 6.2 for the period July 12-14. Sunny and hot conditions with light to moderate winds were forecast due to a slow-moving high pressure weather system over southern Ontario. As a result, an air quality advisory was issued for all of southern Ontario for July 13 and 14. On these two days, ground-level ozone concentrations were forecast to exceed

Figure 6.3
Diurnal Variation of Selected Pollutants at Etobicoke South on July 13, 1997

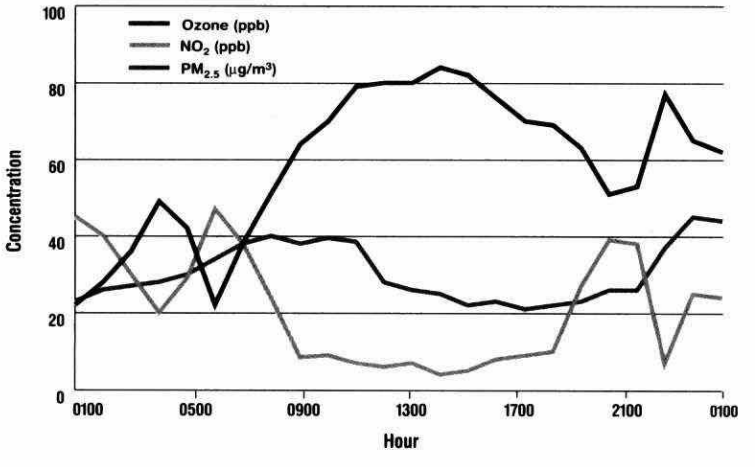
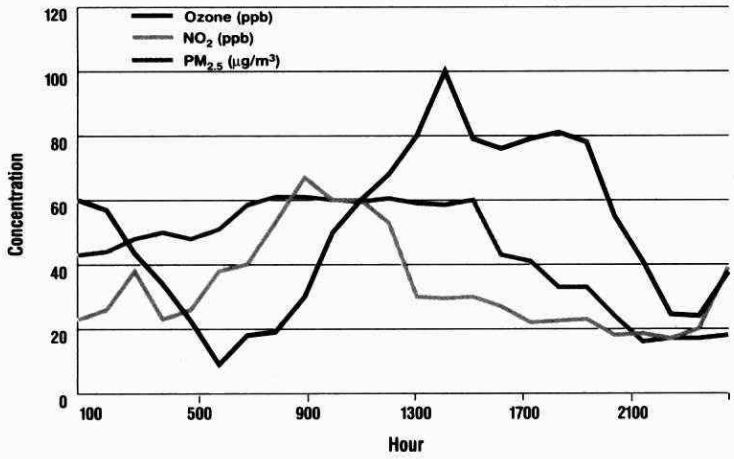
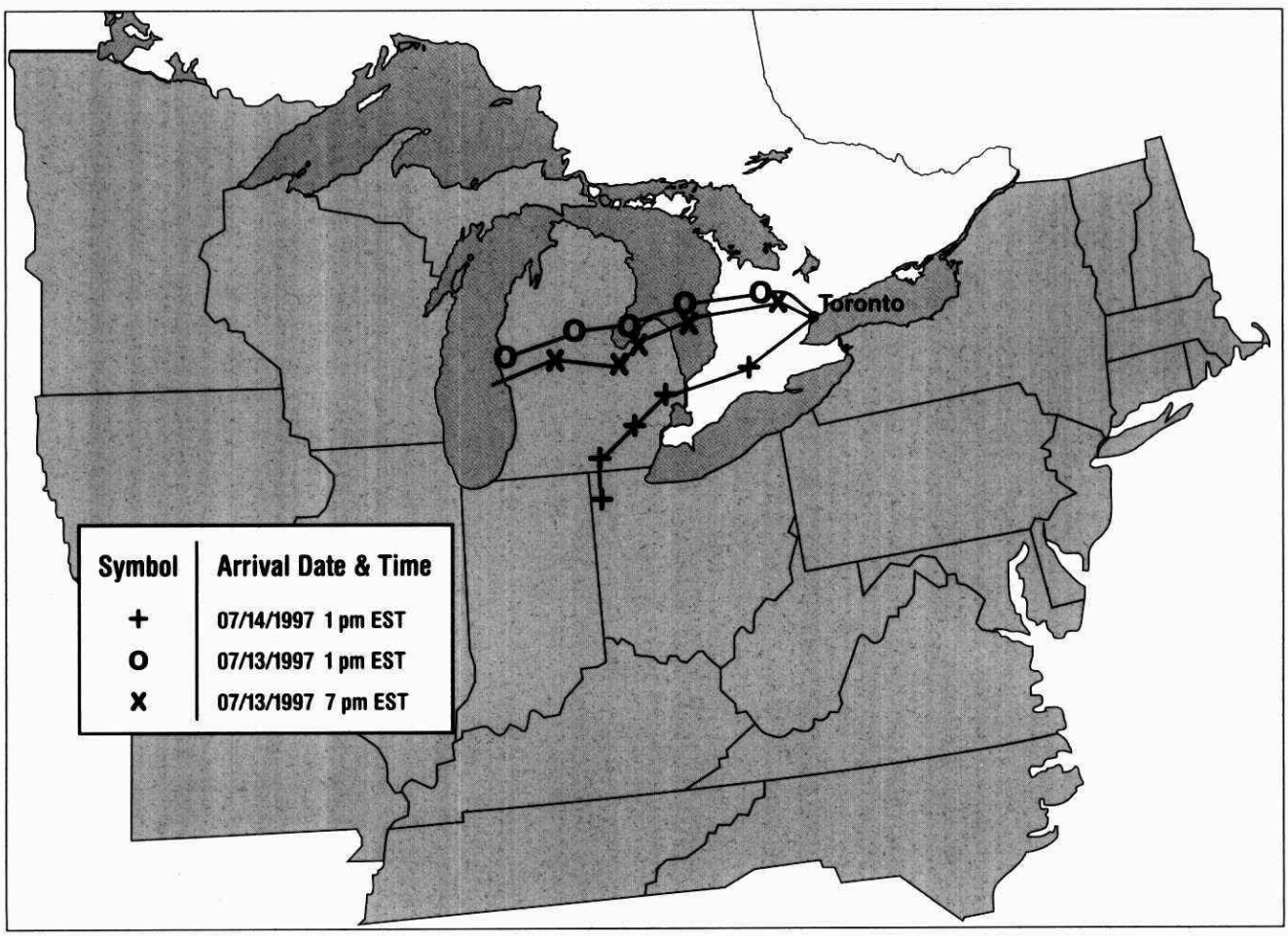


Figure 6.4
Diurnal Variation of Selected Pollutants at Etobicoke South on July 14, 1997



the one-hour Ontario criterion of 80 ppb over large areas of the province. Ozone levels did exceed the one-hour criterion at numerous sites across southern Ontario, including the Greater Toronto Area (Figure 6.2). Both PM_{10} and $PM_{2.5}$ data also showed elevated levels during this period, in particular on July 14. The time series for hourly PM_{10} and $PM_{2.5}$ data recorded at Etobicoke South in Toronto show close correlation between PM_{10} and $PM_{2.5}$ during this three-day period. Daily PM_{10} and $PM_{2.5}$ concentrations averaged 52 µg/m³ and 44 µg/m³ respectively on July 14. Average $PM_{2.5}$ concentrations were approximately 86 per cent of the PM_{10} concentrations during this episode.

Figure 6.5
Air Parcel Back Trajectories into Toronto, at 6 Hour Intervals on July 13 and 14, 1997



The diurnal variation of selected air pollutants during the episode at Etobicoke South in Toronto is shown in Figure 6.3 for July 13 and in Figure 6.4 for July 14. On both days nitrogen dioxide peaks in the morning during periods of limited mixing conditions, while ozone concentration shows a minimum on both days. The ozone minimum is likely due to scavenging by nitric oxide, which is emitted by vehicles. Subsequently, ozone levels start to climb, peaking by mid-afternoon and remaining relatively high throughout the evenings of both July 13 and July 14. Fine particles ($PM_{2.5}$) show a smaller diurnal range with levels somewhat higher in the morning and late evening on July 13, increasing on July 14 as the air mass aged. By late evening on July 14, a change in weather occurred and both ozone and fine particles declined rapidly.

Figure 6.5 depicts the 48-hour back trajectories of air parcels arriving at six-hour intervals in Toronto on July 13 and 14. On these days, air parcels had previously traversed relatively high PM and oxidant precursor emission areas of the U.S. before entering southern Ontario. This example illustrates that, in summer, ozone and PM are often elevated simultaneously during certain synoptic weather conditions that affect southern Ontario.

This episode analysis has produced results very similar to those found previously for Windsor in 1996. It reinforces the notion that southern Ontario is impacted by sources in the U.S. midwest and that there is a definite measurable and significant impact due to ozone, precursors of ozone and fine particles.

Chapter 7

Special purpose monitoring

Air toxics are substances that, based upon their toxicity and likelihood for exposure, have the potential to cause harm to humans and the ecosystem. Air toxics include certain volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), chlorinated pesticides and polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins and furans (PCDD/PCDFs) and trace metals. Some air toxics warrant special concern because they are capable of being transported very long distances in the atmosphere or, as is the case with VOCs, because of their important role in the formation of ground-level ozone and fine particulate matter. Discussion of air toxics in this chapter will be limited to VOCs. VOCs are defined technically as organic compounds having a saturation vapour pressure greater than 10^{-1} Torr at 25 degrees C and 760 millimetres of mercury.

The VOC monitoring data are used to support many key ministry initiatives. Firstly, VOC data are critical to the development and review of ambient air quality criteria (AAQC). By providing current exposure levels, this data can also identify regions of the province where potential compliance problems may occur. Secondly, measurements from a variety of ambient air settings (rural, suburban and urban) can be used to assess general environmental quality and to characterize long-range transport contributions. Thirdly, long-term measurements are desirable to

Figure 7.1
Location of VOC Monitoring Sites (1997)

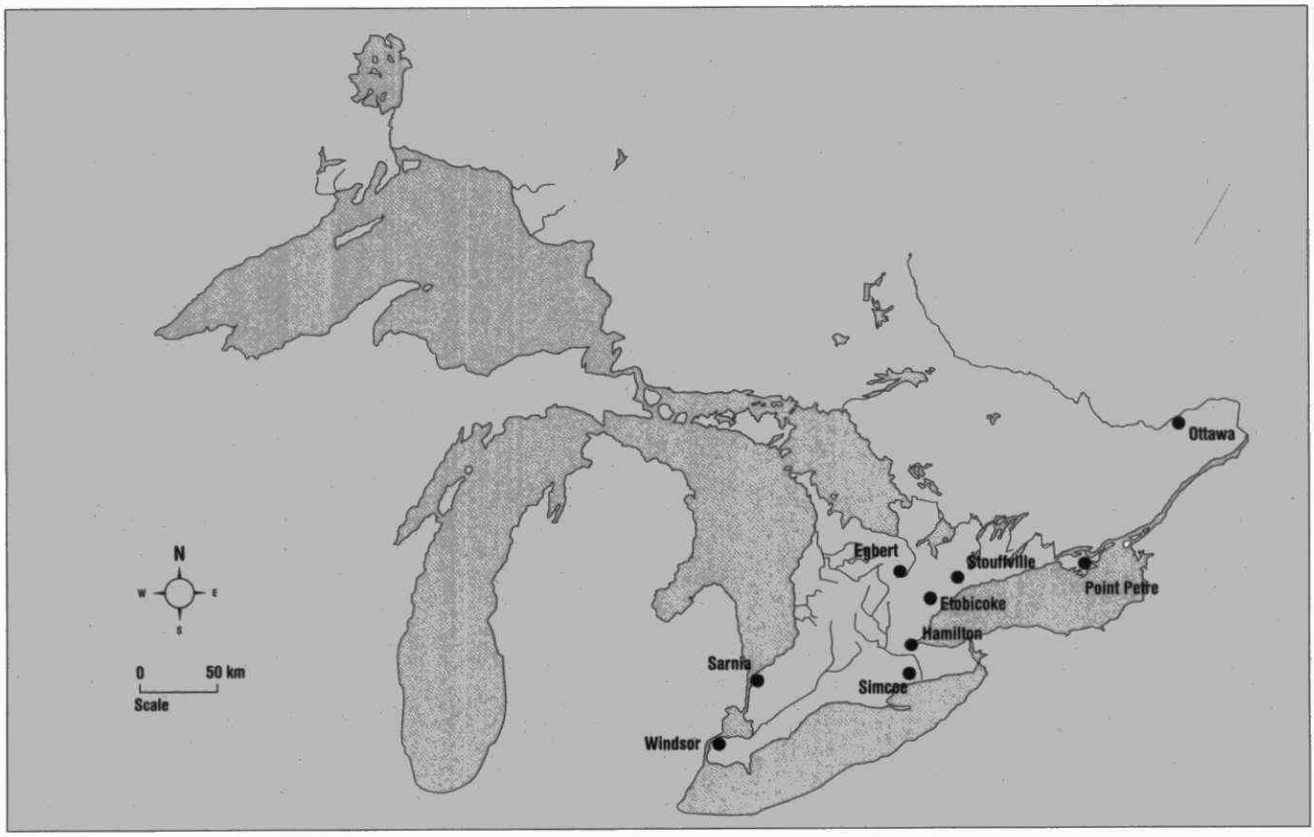


Table 7.1
List of Volatile Organic Compounds (VOCs) Measured

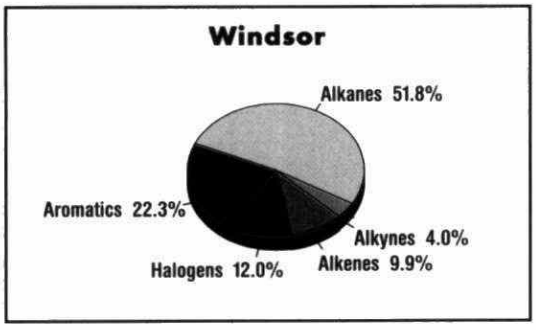
Alkanes	Alkenes	Alkynes	Aromatics	Halogenated
Ethane	Ethylene	Acetylene	Benzene	Freon11
Propane	1,3-Butadiene	1-Butyne	Toluene	Dibromomethane
Butane	1-Butene + Isobutene		Styrene	Carbon tetrachloride
Isobutane	trans-2-Butene		Ethylbenzene	Dibromochloromethane
Cyclopentane	cis-2-Butene		Indane	Bromoform
Pentane	Cyclopentene		iso-Propylbenzene	Bromodichloromethane
Isopentane	Isoprene		n-Propylbenzene	Chloroform
2,2-Dimethylpropane	trans-2-Pentene		sec-Butylbenzene	Chloromethane
Cyclohexane	2-Methyl-1-Butene		tert-Butylbenzene	Dichloromethane
Methylcyclopentane	cis-2-Pentene		iso-Butylbenzene	Freon22
2,2-Dimethylbutane	1-Pentene		Hexylbenzene	Bromomethane
2,3-Dimethylbutane	2-Methyl-2-Butene		m+p-Xylene	Bromotrichloromethane
3-Methylpentane	Cyclohexane		o-Xylene	cis-1,2-Dichloroethylene
2-Methylpentane	1-Methylcyclopentene		3-Ethyltoluene	Bromoethane
Hexane	2-Ethyl-1-Butene		4-Ethyltoluene	Tetrachloroethylene
Methylcyclohexane	cis-2-Hexene		1,3,5-Trimethylbenzene	Chloroethane
2,2,3-Trimethylbutane	1-Hexene		2-Ethyltoluene	Trichloroethylene
3-Methylheptane	3-Methyl-1-Pentene		1,2,4-Trimethylbenzene	trans-1,2-Dichloroethylene
2-Methylheptane	trans-4-Methyl-2-Pentene		1,2,3-Trimethylbenzene	1,2-Dichloroethane
4-Methylheptane	cis-4-Methyl-2-Pentene		1,3-Diethylbenzene	1,1-Dichloroethane
Heptane	4-Methyl-1-Pentene		Napthalene	1,1,2-Trichloroethane
3-Methylhexane	trans-3-Methyl-2-Pentene		p-Cymene	Freon114
2,2-Dimethylpentane	trans-2-Hexene		1,4-Diethylbenzene	Freon12
2,4-Dimethylpentane	cis-3-Methyl-2-Pentene		n-Buytlbenzene	1,1-Dichloroethylene
2,3-Dimethylpentane	1-Methylcyclohexene		1,2-Diethylbenzene	Vinyl chloride
2-Methylhexane	cis-2-Heptene			1,1,1-Trichloroethane
cis-1,4-Dimethylcyclohexane+	trans-3-Heptene			1,1,2,2-Tetrachloroethane
trans-1,3-Dimethylcyclohexane	1-Heptene			Trans-1,3-Dichloropropene
cis-1,3-Dimethylcyclohexane	cis-3-Heptene			1,2-Dichloropropane
trans-1,4-Dimethylcyclohexane	trans-2-Heptene			cis-1,3-Dichloroprpene
trans-1,2-Dimethylcyclohexane	1-Octene			Hexachlorobutadiene
2,2,4-Trimethylpentane	cis-2-Octene			1,4-Dichlorobutane
2,2-Dimethylhexane	trans-2-Octene			Chlorobenzene
Octane	1-Nonene			1,3-Dichlorobenzene
2,4-Dimethylhexane	1-Decene			1,4-Dichlorobenzene
2,5-Dimethylhexane	Propylene			1,2,4-Trichlorobenzene
2,3,4-Trimethylpentane				1,2-Dichlorobenzene
2,2,5-Trimethylhexane				
Nonane				
3,6-Dimethyloctane				
Decane				
Undecane				
Dodecane				

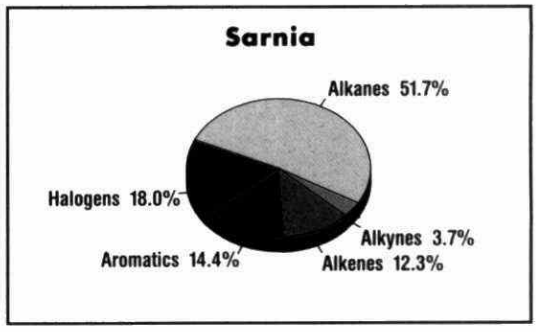
Alkanes are saturated hydrocarbons in which all carbon atoms form a single bond with other atoms. Alkenes are unsaturated hydrocarbons in which some carbon atoms form a double bond with other carbon atoms. Alkynes are unsaturated hydrocarbons in which some carbon atoms form a triple bond with other carbon atoms. Aromatics are compounds where the double-bond carbon atoms occur in a ring-type pattern. Halogenated compounds are hydrocarbons which add or substitute one or more atoms of chlorine, bromine, fluorine or iodene.

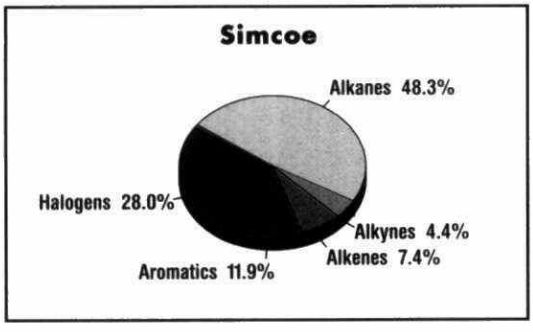
track reductions of ozone precursor VOCs, as projected VOC emission changes outlined in Ontario's Smog Plan and Drive Clean program unfold and, lastly, to reconcile emission inventories.

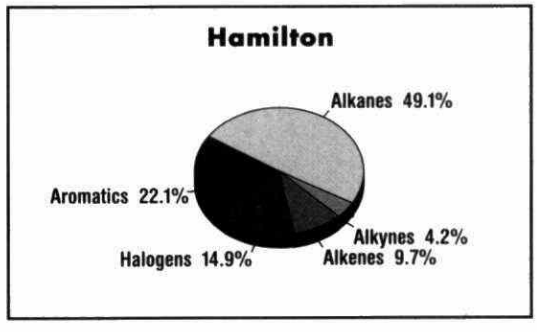
VOCs are emitted into the atmosphere from a variety of sources, including fossil fuel combustion (e.g., vehicle exhaust), heavy industry (e.g., steel-making), petroleum refining, fuel-refilling, industrial

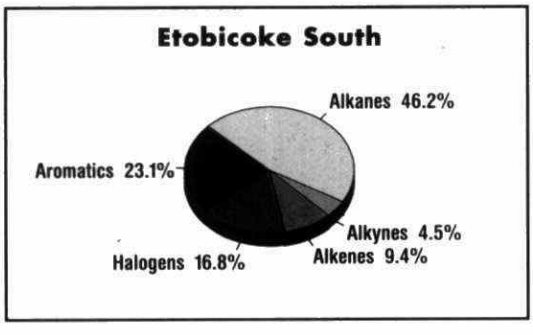
Figure 7.2
Percentage Distribution of VOCs by Class at Sites Across Ontario (1997)

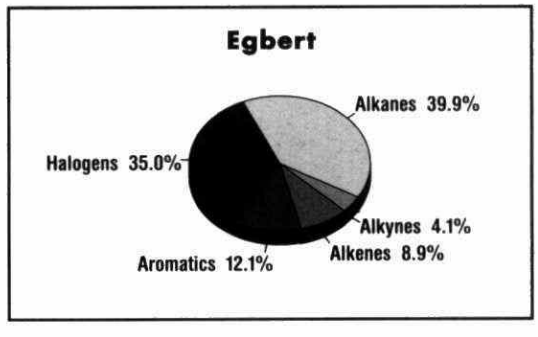


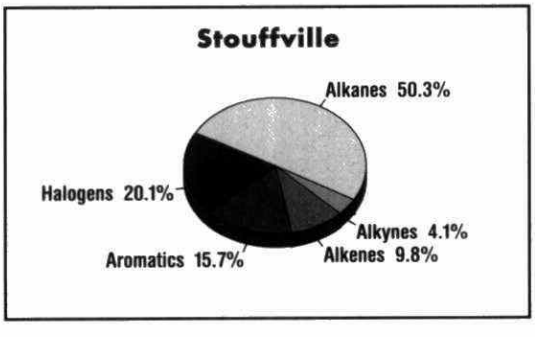


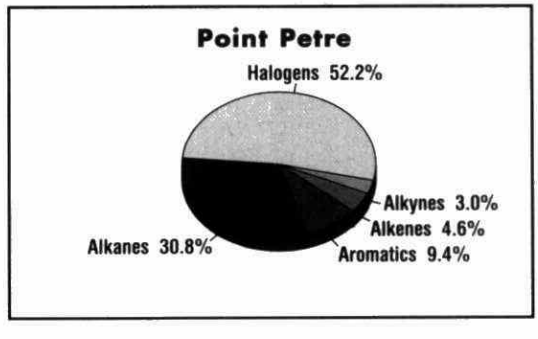












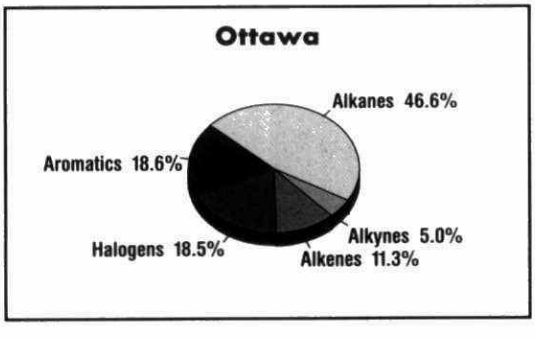
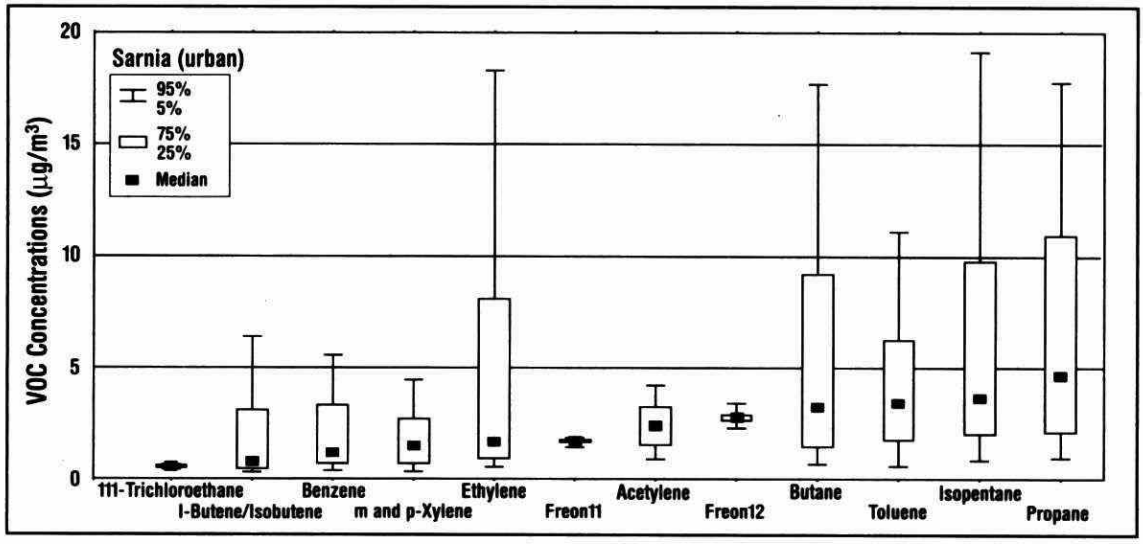
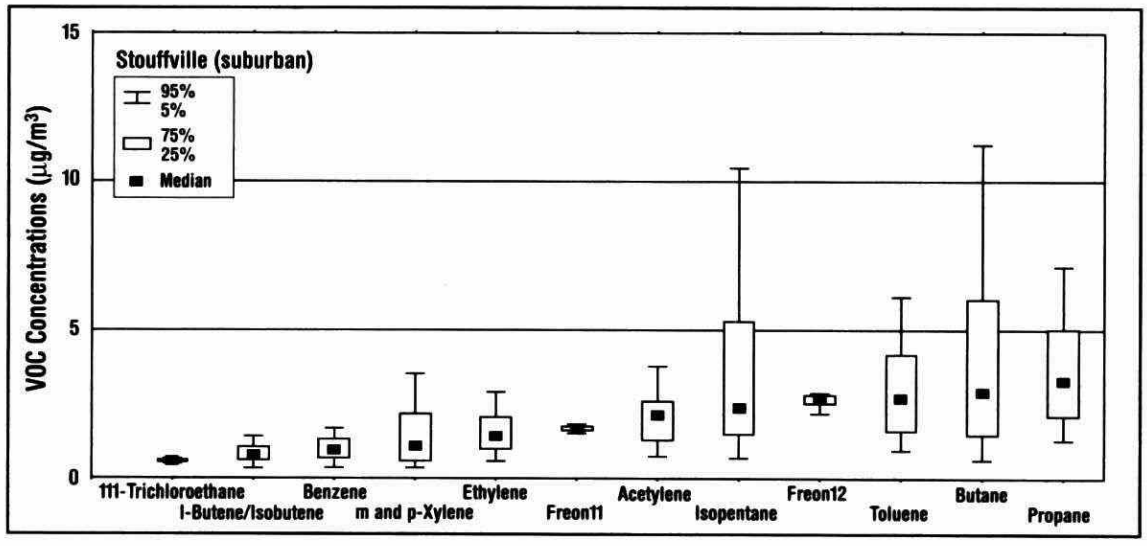
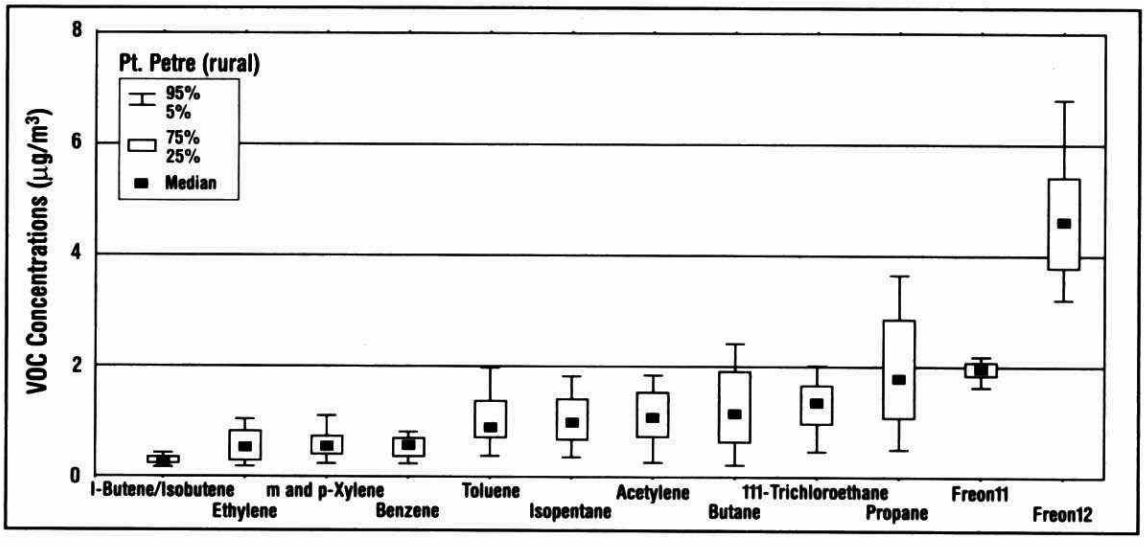


Figure 7.3
Box Plot for Selected VOC Concentrations at an Urban, Suburban and Rural Site (1997)







and residential solvent use, paint application, manufacturing of synthetic materials (e.g., plastics, carpeting), food processing, agricultural activities and wood processing and burning. Specialized, non-routine monitoring and analytical techniques are required to measure VOCs because they are usually present in the atmosphere in gaseous form at ultra-trace concentrations.

As of 1997, VOC monitoring in Ontario has been a co-operative effort between the Ministry of the Environment and Environment Canada (Environmental Protection Service). For purposes of this report, only 1997 data from nine rural, suburban or urban monitoring stations are included in the discussion. Data were excluded from other sites having less extensive data coverage and from sites designated as being strongly source-influenced. The monitoring sites described in this report are shown in Figure 7.1.

VOC samples are collected by automatically drawing ambient air into evacuated stainless steel canisters over a 24-hour period (midnight to midnight), following the National Air Pollution Surveillance sampling schedule (every sixth day). At the Egbert site, intensive (daily) sampling occurred between mid-May and mid-September. Concentrations for 143 selected VOCs, as listed in Table 7.1, were reported for each sample, of which the respective composition consisted of 42 alkanes, 36 alkenes, 2 alkynes, 25 aromatics and 38 halogens.

Summary statistics were calculated for each parameter for each of the nine sampling sites. These statistics appear in the separate appendix document.

The compounds were sorted to identify their relative abundance at their respective sites, based upon their annual average percentage of mass, and to compare relative abundance from site to site. Although compounds like ethane, butane and toluene appear to be the primary VOCs of concern at several sites, based upon annual average percentage of mass, none of these pollutants is really distinguishable from the second or third leading compound. However, one feature that is discernible relates to the type of monitoring site – one or two VOCs are clearly more predominant (i.e., greater than 10 per cent of the mass) at rural type sites (Egbert, Pt. Petre and Simcoe), while all VOCs are less than 10 per cent of the mass at the suburban or urban type sites.

It should also be noted that, although certain compounds are more abundant at a number of sites, this abundance is not consistent from site to site. For example, ethane's annual average percentage of mass varies from 14.5 per cent at Egbert to 7.6 per cent at Sarnia. Two other notable observations concerning relative abundance are consistent from site to site: firstly, at each site a subset of about 40 compounds (of the 143 compounds in total) typically constitute about 90 per cent of the mass of the samples and these 40 compounds are invariably detected in each sample; secondly, the combined mass for benzene, m- and p-xylene and carbon tetrachloride typically constitutes only 4-6 per cent of the total sample mass

It is more appropriate to evaluate relative abundance of VOCs at each of the sites based upon compound class. The relative abundance of VOC classes at each site is shown in Figure 7.2. Clearly, alkanes are the predominant VOC class, accounting for one-half of the total mass of samples for all sites except Pt. Petre. Pt. Petre is dominated by halogens, which are VOCs usually with extended atmospheric residence times and subjected to long-range transport. The other rural sites also have a strong halogen component. The urban and suburban profiles are remarkably similar with little variation noted between VOC class. The typical urban composition is 46-52 per cent alkanes, 9-12 per cent alkenes, 4-5 per cent alkynes, 14-23 per cent aromatics and 12-20 per cent halogens.

Another approach at assessing the relative importance of individual VOCs and the site-to-site variability is illustrated by box-and-whisker plots (Figure 7.3). Again, the distinction between rural versus urban and suburban sites is shown. At rural sites, median concentrations are typically one-half those observed at suburban and urban sites (i.e., 0.5 to 2 $\mu g/m^3$ versus 1 to 5 $\mu g/m^3$). Likewise, the variability in VOC concentrations is greatest at suburban and urban sites, while rural site concentrations have less variability because these sites are less susceptible to nearby source influences.

General environmental quality remains good in relation to airborne VOCs. Concentrations of VOCs exist at trace levels and are well below existing provincial criteria.

Chapter 8

Regional/national/international air quality perspective

How does Toronto's air quality measure up ?

The purpose of this section is to compare air quality levels in Toronto with those measured regionally, nationally and on an international basis. To do this, in early 1998 the Ontario Ministry of the Environment requested ambient air quality data from 93 cities in some 65 countries worldwide. Thirty-three cities responded with air quality data that could be used in a comparison with Toronto's. Their metropolitan populations ranged from about 0.1 million (Halifax) to 20 million (Mexico City).

Data from all available monitoring sites within the metropolitan areas of each city were requested because it was felt that this would be more representative of average city air quality than data from a select number of sites. It should be pointed out that monitoring methods and siting procedures may vary from country to country; therefore comparisons among nations are subject to caution. Since the form of air quality standards may vary from country to country, the inter-city comparisons presented here are referenced to ambient air quality criteria (AAQC) for Ontario and the national ambient air quality standards (NAAQS) for the United States.

As noted in previous sections of this report, Ontario has made significant reductions to key air pollutants but smog remains a growing concern, especially in large urban centres such as Toronto. Since ozone and fine particles are the two main components of smog, and of greatest health concern, it is these two pollutants that we will show regionally, nationally and internationally.

In Ontario, including Toronto, a major cause of elevated ozone is attributed to the transport of ozone and its precursors from outside Ontario; e.g., regional transport. Figure 8.1 shows the range of maximum one-hour ozone levels in selected U.S. cities for the period 1988 to 1996. Vancouver and Montreal are also included to give a national perspective on the ozone problem. All four U.S. cities (New York, Chicago, Detroit and Cleveland) record higher ozone levels than Toronto. Of the three Canadian cities, Toronto records the highest levels, followed by Montreal and Vancouver. Internationally, Toronto ranks 13th of 33 cities when it comes to one-hour maximum ozone concentrations during 1996 (see Figure 8.2). The highest one-hour concentrations were measured in Mexico City (323 ppb), Sao Paulo (190 ppb) and Detroit (184 ppb). Of the 33 cities reporting, 11 exceeded the U.S. NAAQS (120 ppb) while 30 cities exceeded the more restrictive Ontario one-hour AAQC of 80 ppb. Of the Canadian cities considered, Montreal recorded the highest one-hour concentration (113 ppb) followed by Toronto (103 ppb) and Vancouver (94 ppb). It should be re-emphasized here that hourly values of ozone vary from year to year, depending on such factors as precursor emissions and weather conditions.

Figure 8.1
Range of Maximum 1-Hour Ozone Concentrations in Selected Cities (1988-1996)

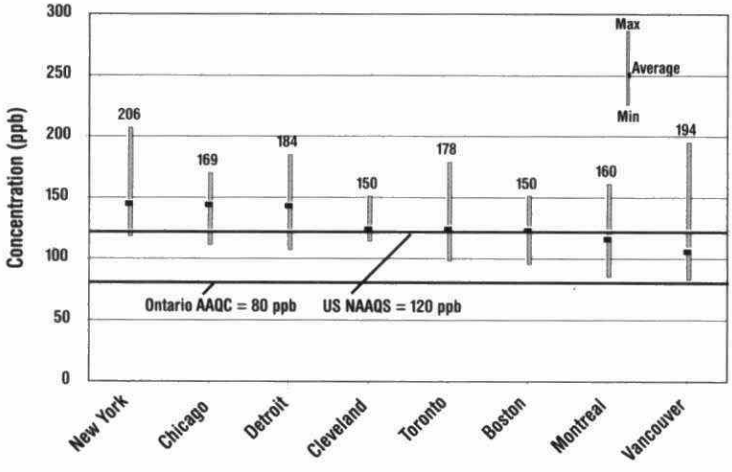


Figure 8.2
Maximum 1-Hour Ozone Concentrations in Selected World Cities (1996)

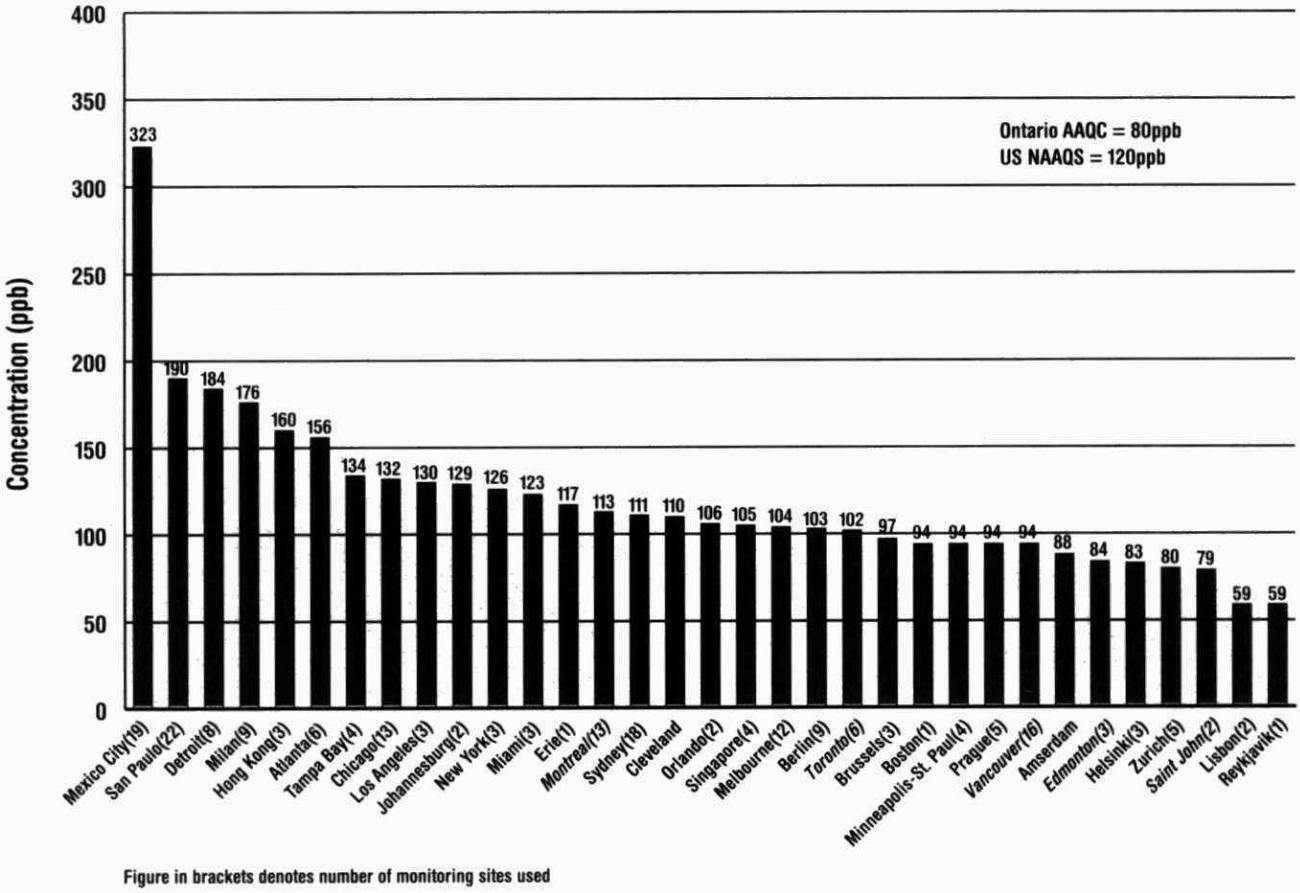
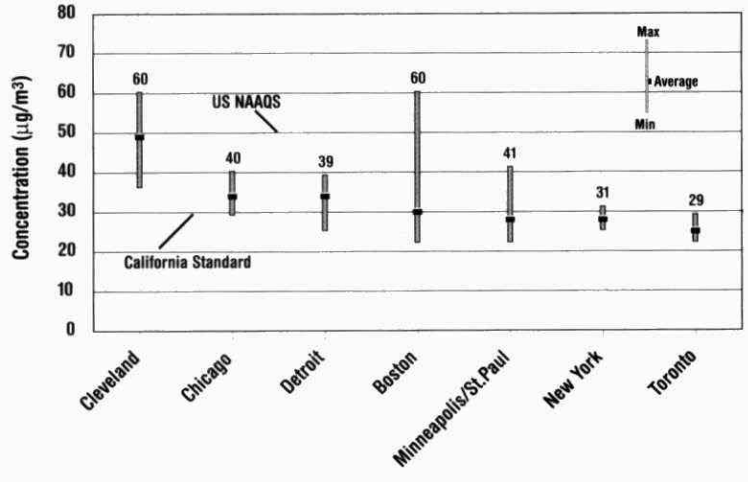


Figure in brackets denotes number of monitoring sites used

Figure 8.3
Range of Annual PM_{10} Means in Selected Cities (1988-1996)



For PM_{10}, the other key ingredient of smog, regional levels are shown in Figure 8.3. Over the nine-year period (1988-1996), Toronto recorded the lowest composite annual inhalable particle levels. Toronto is the only site that did not exceed the U.S. annual standard (50 µg/m³) or the more restrictive California annual standard (30 µg/m³) over the nine-year period. Internationally, Toronto ranks in the middle when it comes to annual mean PM_{10} levels during 1996, tied for 13th of 27 cities (Figure 8.4). The worst cities were Mexico City (73 µg/m³) and Sao Paulo (66 µg/m³) and the best Vancouver (14 µg/m³) and Sydney (15 µg/m³).

Figure 8.4
Annual Mean PM_{10} in Selected World Cities (1996)

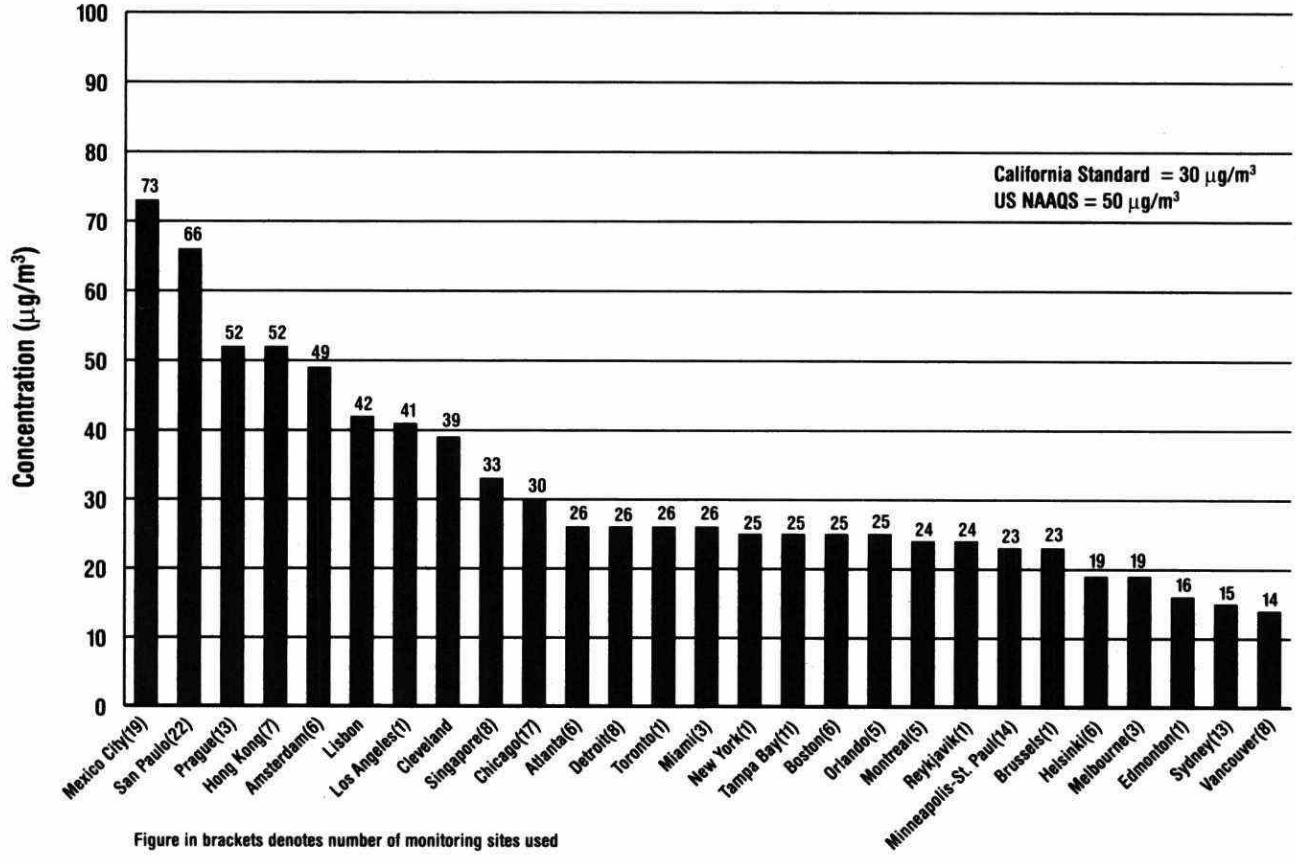


Figure in brackets denotes number of monitoring sites used

Data analysis strongly implicates neighbouring U.S. states as being significant contributors to high levels of ozone and fine particles in southern Ontario. It is also clearly evident that because of their significant health impacts, the ozone and fine particle issues are important from a local, regional, national and international perspective.

Chapter 9

Future directions

Since the first edition of this report in 1971, there has been consistent improvement in the province's air quality, even as the population has grown. For example, significant decreases have been achieved for sulphur dioxide, carbon monoxide, total suspended particulate matter, nitrogen oxides and total reduced sulphur compounds.

Encouraging as this is, however, there is still a great deal of work to be done, and the Ontario government is directing increased emphasis to ozone and inhalable and respirable particles (PM_{10} and $PM_{2.5}$), for which recent scientific evidence suggests significant health effects.

Ground-level ozone remains a concern, as does PM_{10}. In 1997 there were a number of days on which levels exceeded the Ontario 24-hour interim PM_{10} criterion of 50 $\mu g/m^3$. For ambient urban sites the highest percentage of days (9 per cent) occurred in Windsor, a city strongly influenced by long-range transport and trans-boundary effect. A significant number of days of PM_{10} exceeding the interim criterion were also noted in Cornwall (6.5 per cent) and Toronto (5.8 per cent), locations with significant local sources.

Data analysis strongly implicates neighbouring U.S. states – namely, Ohio, Michigan, Illinois, Indiana and New York – as being significant contributors to high levels of fine particles and ozone in southern Ontario. The contributions from long-range transport and trans-boundary movement of air pollution and from local sources need further assessment.

Because of the potential health and environmental effects of these two key ingredients of smog, continued monitoring is required to evaluate trends and determine the effectiveness of reduction and abatement strategies.

Ontario has begun to change its existing monitoring network by deploying real-time monitors of inhalable and respirable particles. These are being phased in over the next few years. In 1997 there were 11 ambient monitors of $PM_{10}/PM_{2.5}$ for which data from the AQI monitoring network were available. The collection and assessment of such data from the AQI monitoring network will allow future improvements to the Air Quality Index (AQI) and air quality advisory programs by including fine particle measurements as a key element, along with ozone.

The Ontario government has committed itself fully to improving air quality with a series of initiatives. Foremost of these is its Drive Clean program, which started in spring 1999 and required emission testing of light-duty vehicles, followed by repairs where necessary. In the fall of 1999, the ministry will launch its new heavy vehicle emissions testing program to reduce emissions from trucks, buses and other heavy duty vehicles.

Other ongoing activities include:

- Ontario's Smog Plan, a government-industry partnership that commits 44 organizations to reduction of smog-causing emissions;
- updating of air quality standards and regulations to make them better, clearer and stronger, including a standard for inhalable particles;
- less polluting blends of gasoline mandated during the summer – resulting in 18,000 fewer tonnes of smog-causing compounds annually;
- strong environmental protection measures being built into the design of a competitive electricity market;
- $4 million spent since 1995 on the province's air monitoring network, as well as a new air monitoring bus;
- public education, which includes Partners in Air for high school students and Smog Rover, a mobile van that identifies significant polluting vehicles on Ontario's roads;
- an ongoing campaign to persuade neighbouring U.S. states to toughen their air quality regulations – which would lessen trans-boundary pollution.

Along with the contributions of concerned citizens, organizations and industries, these initiatives will go a long way toward improving the quality of Ontario's air.

Glossary

Acidic deposition refers to deposition of a variety of acidic pollutants (acids or acid-forming substances such as sulphates and nitrates) on biota or land or in waters of the earth's surface.

Air quality advisory an alert issued to the public when elevated pollution levels are forecast due to ground-level ozone.

Air Quality Index real-time information system that provides the public with an indication of air quality in major cities across Ontario.

AQI station continuous monitoring station in a built up area, used to inform the public of air quality levels on a real-time basis; station must report on at least ozone and suspended particles to be classified AQI.

Air Pollution Index basis of Ontario's alert and control system to warn of deteriorating air quality; derived from 24-hour running averages of sulphur dioxide and suspended particles.

Ambient air outdoor or open air.

Carcinogen an agent that incites carcinoma (cancer) or other malignancy.

Continuous pollutant contaminant for which a continuous record exists; effectively, pollutants that have hourly data (maximum 8760 values per year).

Continuous station where pollutants are measured on a real-time basis and data determined hourly (as for ozone, sulphur dioxide).

Criterion maximum concentration or level (based on potential effects)of contaminant that is desirable or considered acceptable in ambient air.

Daily pollutant contaminant with a 24-hour or daily value (maximum 365 values per year).

Detection limit minimum concentration of a contaminant that can be determined.

Fossil fuels natural gas, petroleum, coal and any form of solid, liquid or gaseous fuel derived from such materials for the purpose of creating heat.

Gas chromatography separation technique involving passage of a gaseous moving phase through a column containing a fixed absorbent phase; used principally as a quantitative analytical technique for volatile compounds.

Geometric mean statistic of a data set calculated by taking the nth root of the product of all (n) values in a data set. Provides a better indication than arithmetic mean of the central tendency for a small data set with extreme values.

Global warming long-term rise in the average temperature of the earth; principally due to an increase in the buildup of carbon dioxide and other greenhouse gases.

Ground-level ozone colourless gas formed from chemical reactions between nitrogen oxide and hydrocarbons in the presence of sunlight near the earth's surface.

Inhalable particles represents up to 60 per cent of the total suspended particulate matter; composed of both primary (diameter 2.6 to 10.0 microns) and fine (diameter $\leq$ 2.5 microns) particles; also referred to as PM_{10}.

Micron a millionth of a metre; symbol μ

Median middle value of a set of numbers arranged in order of magnitude.

Monthly pollutant contaminant for which there exists only a monthly (30-day) value (maximum 12 values per year).

Non-continuous station station that measures pollutant concentration on a daily, six-day frequency or monthly cycle (as for total suspended particulate matter).

Ozone episode day a day on which widespread (hundreds of kilometres) elevated ozone levels (greater than 80 ppb maximum hourly concentration) occur simultaneously.

Particulate matter refers to any airborne finely divided solid or liquid material with an aerodynamic diameter smaller than 100 microns.

Percentile value percentage of the data set that lies below the stated value; if the 70 percentile value is 0.10 ppm, then 70 per cent of the data are equal to or below 0.10 ppm.

Photochemical oxidant any of the chemicals that enter into oxidation reactions in the presence of light or other radiant energy.

Photochemical reaction chemical reaction influenced or initiated by light, particularly ultraviolet light.

Photochemical smog see *smog*.

Primary pollutant contaminant emitted directly to the atmosphere.

Respirable particles particles smaller than about 2.5 microns in diameter, which arise mainly from condensation of hot vapours and chemically driven gas to particle conversion processes; also referred to as $PM_{2.5}$. These are fine enough to penetrate deeply into the lungs and have the greatest effects on health.

Secondary pollutant contaminant formed from other pollutants in the atmosphere.

Smog a contraction of smoke and fog; colloquial term used for photochemical fog, which includes ozone and other contaminants; tends to be a brownish haze.

Stratosphere atmosphere 10 to 40 kilometres above the earth's surface.

Stratospheric ozone ozone formed in the stratosphere from the conversion of oxygen molecules by solar radiation; ozone found there absorbs much ultraviolet radiation and prevents it from reaching the earth.

Suspended particles suspended particulate matter most likely to reach the lungs (diameter less than 5-10 microns).

Torr unit of pressure equal to 1/760 of standard atmosphere.

Total suspended particulate matter generic term for airborne particles including smoke, fume, dust, fly ash and pollen; approximately 0.1 to 100 microns in diameter.

Toxic deposition absorption or adsorption of a toxic pollutant at vegetative or ground levels.

Toxic pollutant substance that can cause cancer, genetic mutations, organ damage, changes to the nervous system, or even physiological harm as a result of prolonged exposure, even to relatively small amounts.

Troposphere atmospheric layer extending about 10 kilometres above the earth's surface.

Abbreviations

AAQC	ambient air quality criteria (Ontario)
API	air pollution index
AQI	air quality index
AQUIS	air quality information system
CO	carbon monoxide
CO_2	carbon dioxide
COH	coefficient of haze reported as SP
EC	Environment Canada
EMRB	Environmental Monitoring and Reporting Branch
EST	Eastern Standard Time
H_2S	hydrogen sulphide
INS	insufficient data to calculate statistic
IP	inhalable particles
LIMA	Lambton industry meteorological alert
MOE	Ministry of the Environment
NAAQS	national ambient air quality standard (U.S.)
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
O_3	ozone
OEIS	Ontario emission inventory system
$PM_{2.5}$	particles less than 2.5 microns
PM_{10}	particles less than 10 microns
RP	respirable particles
SO_2	sulphur dioxide
SO_X	sulphur oxides
SP	suspended particles
TRS	total reduced sulphur
TSP	total suspended particles
USEPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
$g/m^2/30$ days	grams (of contaminant) per square metre per 30-day period
kg	kilogram
kt	kilotonne
$\mu g/m^3$	micrograms (of contaminant) per cubic metre (of air)
pg/m^3	picograms, i.e. a millionth of a microgram (of contaminant) per cubic metre (of air)
ppb	parts (of contaminant) per billion (parts of air)
ppm	parts (of contaminant) per million (parts of air)

References

1. Burnett, R.T., Dales, R.E., Krewski, D., Vincent, R., Dann, T., and Brook, J.R., 1995: Associations Between Ambient Sulphate Particles and Admissions to Ontario Hospital for Cardiac and Respiratory Diseases. American Journal of Epidemiology, Vol 142, pp15-22.

2. Brook, J.R., Dann, T. and Burnett, R.T., 1997: The Relationship Among TSP, PM_{10}, $PM_{2.5}$ and Inorganic Constituents of Atmospheric Particles Matter at Multiple Canadian Locations. Journal of Air and Waste Management Association, Vol 46, pp2-18.

3. Environment Ontario, 1998. Air Quality in Ontario 1996 - A Concise Report on the State of Air Quality in the Province of Ontario.

4. Environment Ontario, 1998. Air Quality in Ontario 1996 - Appendix.

5. Fraser, D., Yap, D., Kiely, P. and Mignacca, D. 1991. Analysis of Persistent Ozone Episodes in Southern Ontario 1980-1991. Technology Transfer Conference, Toronto, 1991. Proceedings AP14, pp 222-227.

6. Fraser, D., Yap, D., Kiely, P., De Brou, G., Dong, W. 1997. Daily and Continuous Monitoring of PM10, /PM2.5 in Ontario. Presented at the 90th Air and Waste Management Association, Toronto, Ontario. June 1997.

7. Fraser, D., Yap, D., Fudge, D., Misra, P.K. and Kiely, P., 1995. A Preliminary Analysis of Recent Trends in Ground-Level Ozone Concentrations in Southern Ontario. Presented at the 88th Air and Waste Management Association, San Antonio, Texas. June 1995.

8. Kiely, P., Yap, D., De Brou, G.B., Fraser, D. and Dong, W., 1997. A Comparative Study of Toronto's Air Quality and Selected World Cities. Presented at the 90th Air and Waste Management Association, Toronto, Ontario. June 1997.

9. Lioy, P. et al., 1991. Assessing Human Exposure to Airborne Pollutants. Environmental Science and Technology Vol. 25, pp. 1360.

10. Lipfert, F.W. and Hammerstrom, T. 1992. Temporal Patterns in Air Pollution and Hospital Admissions. Environmental Research, Vol. 59, pp. 374-399.

11. Lippmann, M. 1991. Health Effects of Tropospheric Ozone. Environmental Science and Technology, Vol. 25, No. 12, pp. 1954-1962.

12. Pengelly, L.D., Silverman, F. and Goldsmith, C.H. 1992. Health Effects of Air Pollution Assessed Using Ontario Health Survey Data. Urban Air Group, McMaster University.

13. Rethinking the Ozone Problem in Urban and Regional Air Pollution. National Academy Press, Washington D.C., 1991.

14. United States Environmental Protection Agency, National Air Quality and Emission Trends, 1997.

15. Wolff, G.T., Kelley, N.A. and Ferman, M.A., 1982. Source Regions of Summertime Ozone and Haze Episodes in the Eastern U.S. Water, Air and Soil Pollution, 18: pp 65-81.

16. Yap, D., Fraser , D., Kiely, P., De Brou, G. and Dong, W. 1997. The Role of Trans-boundary Flow on 1995 Ozone Levels in Ontario. Presented at the 90th Air and Waste Management Association., Toronto, Ontario, June 1997.

17. Yap, D., Ning, D.T. and Dong, W., 1988. An Assessment of Source Contribution to the Ozone Concentrations in Southern Ontario. Atmospheric Environment, Vol. 22, No. 6, pp 1161-1168.

18. Written Communication from J. Lane, Air Quality Surveillance Branch, Lawrence, Massachusetts, 1998.

19. Written Communication from K. Stubbs, Air Quality and Source Control Department, GVRD, Burnaby, B.C. 1998.

20. Written Communication from L. Kolczak, South Coast, Air Management District, Diamond Bar, California, 1998.

21. Written Communication from G. Eckhardt, Minnesota, Pollution Control Agency, St. Paul, Minnesota, 1998.

22. Written Communication from W. Delaware, New York State, Department of Environment, Albany, New York, 1998.

23. Written Communication from G. Engler, DH10 Environmental Protection Agency, Columbus, Ohio, 1998.

24. Written Communication from M. Bisson, Quebec, 1998.

25. Written Communication from A. Betts, EPA New South Wales, Australia, 1998.

26. Written Communication from R. Haudenschild, Air Pollution Control Division, Switzerland, 1998.

27. Written Communication from C. Mulkey, Ambient Monitoring Section, State of Florida, 1998.

28. Written Communication from A. Chang, Hong Kong Government, Environmental Protection Department, 1998.

29. Written Communication from J. Osmo, Helsinki Metropolitan Area Council, Environmental Office, 1998.

30. Written Communication from Jose Luis Pedroza Serrano, Director de la Red Automatica de Monitoreo Atmosferico, Mexico, 1998.

31. Written Communication from Mary Ann Heindorf, Department of Natural Resources, Lansing, Michigan, 1998.

32. Written Communication from R. Piercey, Nova Scotia Department of Environment, Halifax, Nova Scotia, 1998.

33. Written Communication from Kim Martin, Illinois EPA, Springfield, Illinois, 1998.

34. Written Communication from R. Saharom, Ministry of Environment, Singapore, 1998.

35. Written Communication from J. Romano, Escola Técnica de Saneamento, Brazil, 1998.

36. Written Communication from Dr. D. Schwela, WHO, Geneva, 1998.

37. Written Communication from Graca Espada, Direccao Geral do Ambiente, Portugal, 1998.

38. Written Communication from P.R. den Hertog, National Institute of Public Health and Environment, Amsterdam, 1998.

39. Written Communication from S. Lloyd, Director Pollution Control, Pretoria, South Africa, 1998.

40. Written Communication from Dr R. Gualdi, U.O. Fisica & Tutela Dell Ambiente, Milano, Italy 1998.

41. Written Communication from J. Fiala, Air Quality Information System, Czech Republic, 1998.

42. Written Communication from Dr. D. Rasse, Brussels, 1998.

43. Written Communication from H. Diekmann, Berlin, 1998.

44. Written Communication from Dr. L. Viras, Directorate of Air and Noise Control, Athens, Greece, 1998.

45. Written Communication from R. Hughes, Department of Environment, Fredericton, New Brunswick, 1998

46. Written Communication from Jon Benjaminsson, Department of Environmental Control, Reykjavik City, Iceland, 1998.

58. Written Communication from B. Myrick, Air Issues and Monitoring Branch, Edmonton, Alberta, 1998.

1M 11/99

ISBN 0-7778-9169-7

Printed on 100% recycled paper
including 75% post-consumer fibre

pibs 3909e